Quadrilateral Mesh Generation for Large Deformations

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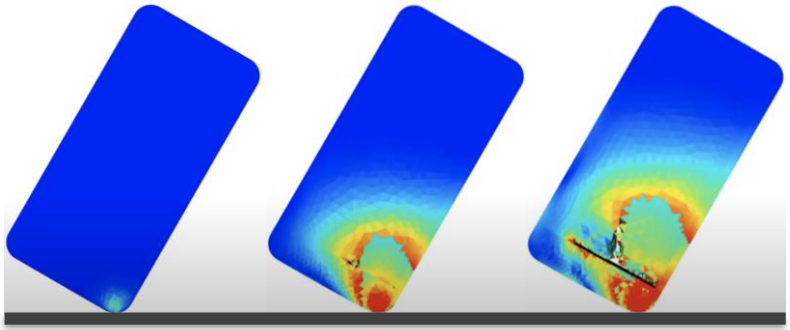
Why meshing?

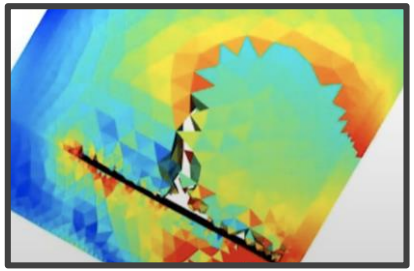
Numerical simulation of physical processes



Phone drop

Images from [OnScale]
https://www.youtube.com/watch?v=gVz3eJrMMmM

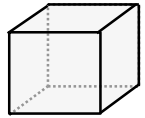
- **Meshing simplifies hugely numerical simulation**



- Simulation convergence depends on the mesh

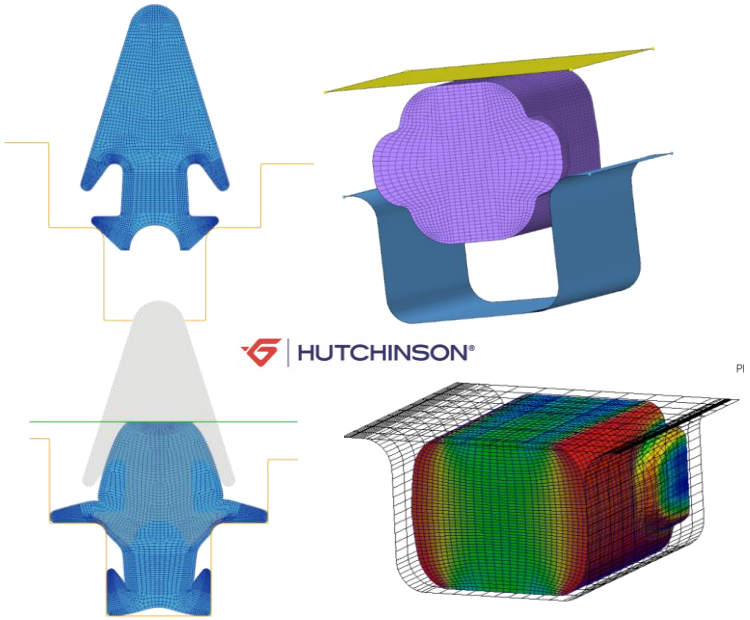
Why quadrilateral meshing?

Numerical simulation of large deformations



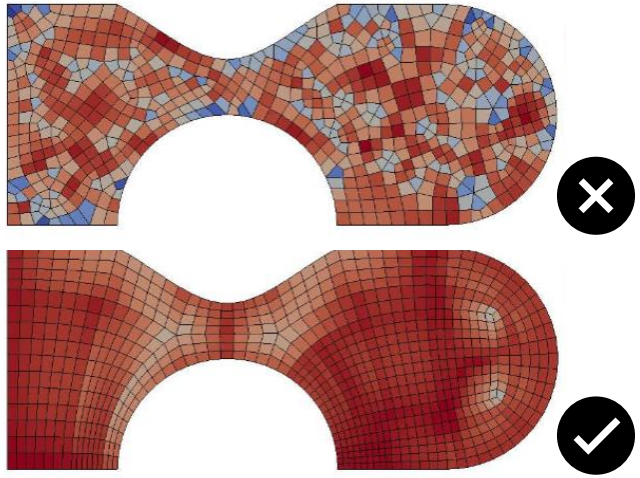
For mechanics of hyper-elastic materials :

- In 2D, structured quadrilaterals are required
- In 3D, structured hexahedras are required



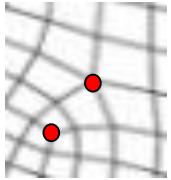
Challenges

Unstructured quad mesh is not usable



Mesh quality

- Alignment with boundaries
- 90° angles
- Few number of singularities

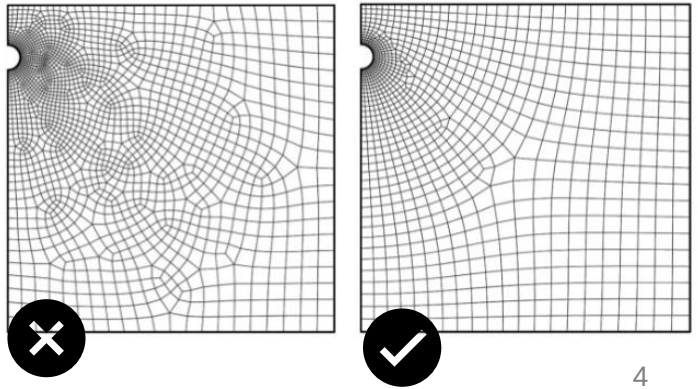


No general algorithm

Human intervention

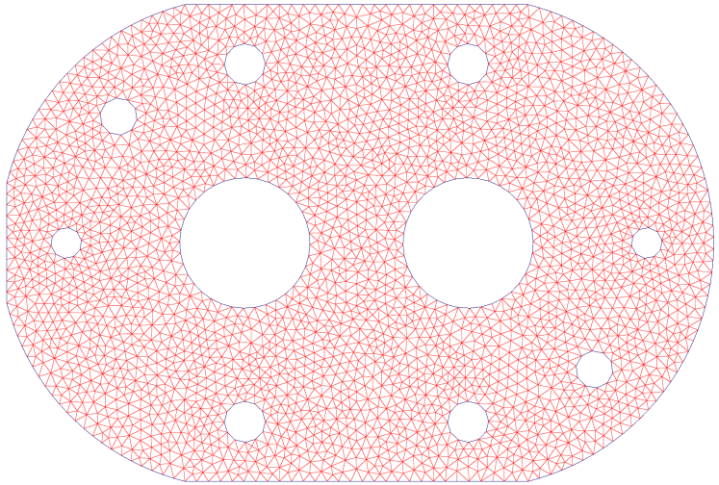
Block subdivision & model fixing

Several days to build one mesh

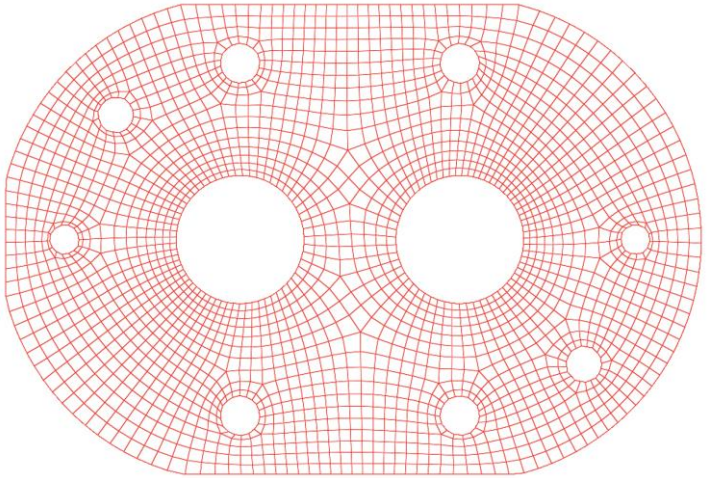


Objectives

Accelerate the generation of high quality quadrilateral meshes for large deformations



Input : triangular mesh

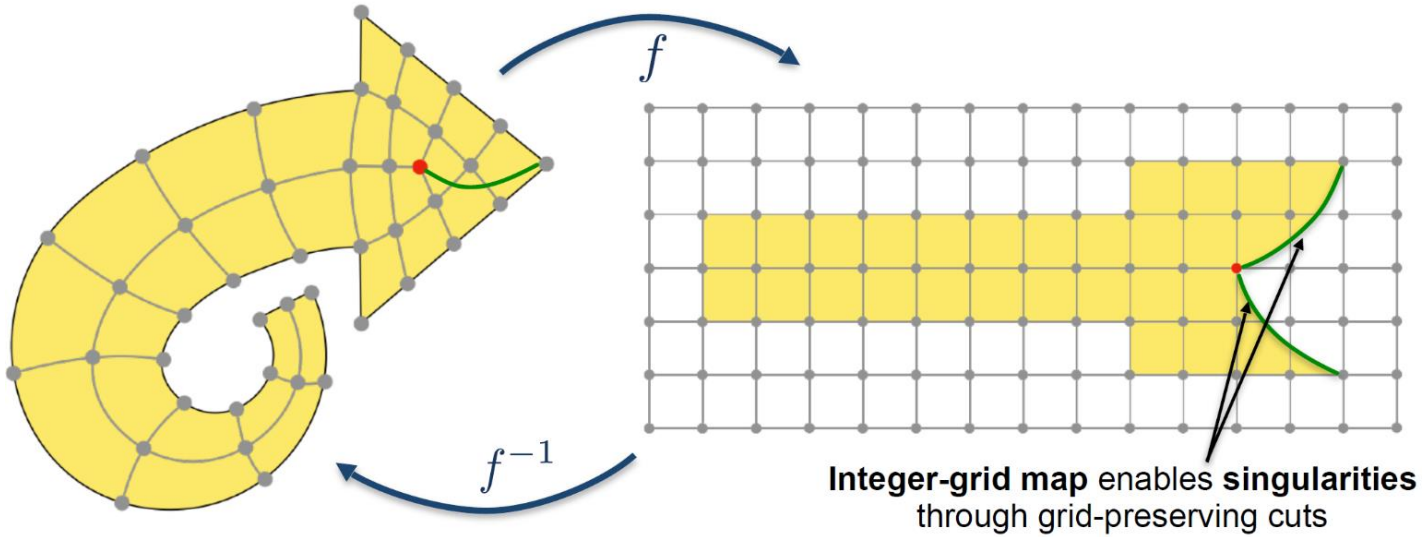


Output : structured quadrilateral mesh
< 1 minute

Intuition

Global parameterization

Map a 2D domain to a regular grid

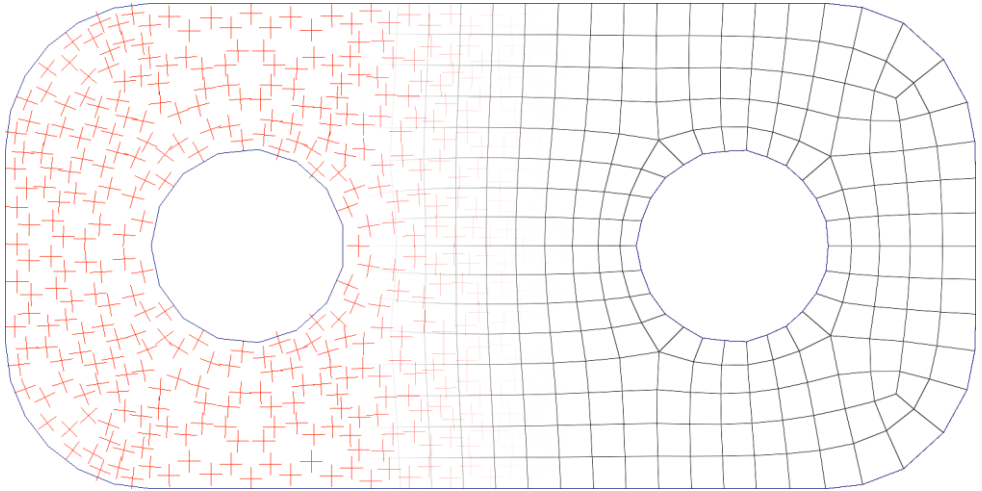


Algorithm overview

Frame-field based mesh generation

1. **Compute frame-field**
   - gives local orientation
   - gives singularities positions

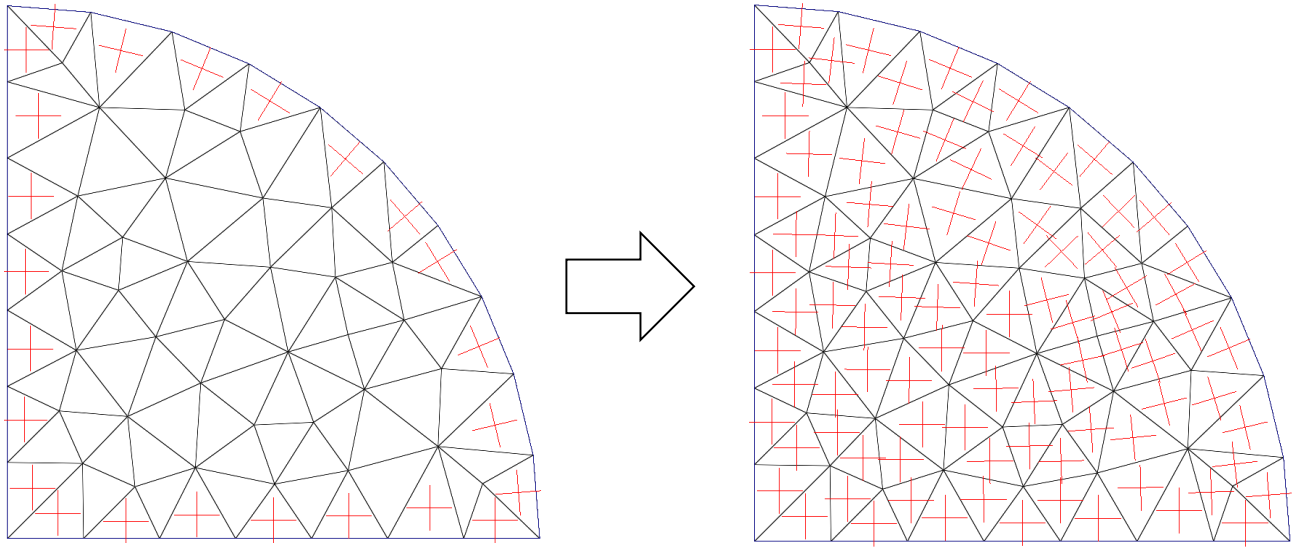
2. **Compute quads**



1. Frame-field computation

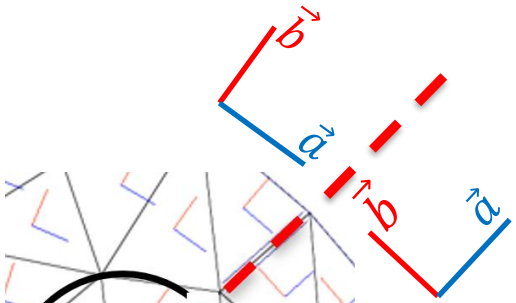
Input: triangle mesh

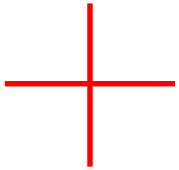
1. Initialization: set crosses on boundaries
2. Interpolation

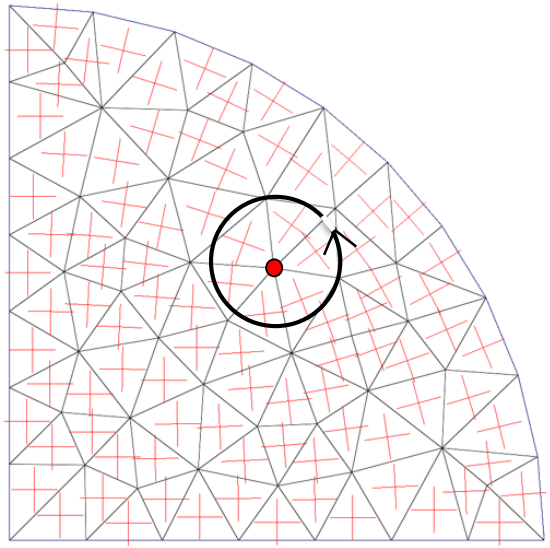


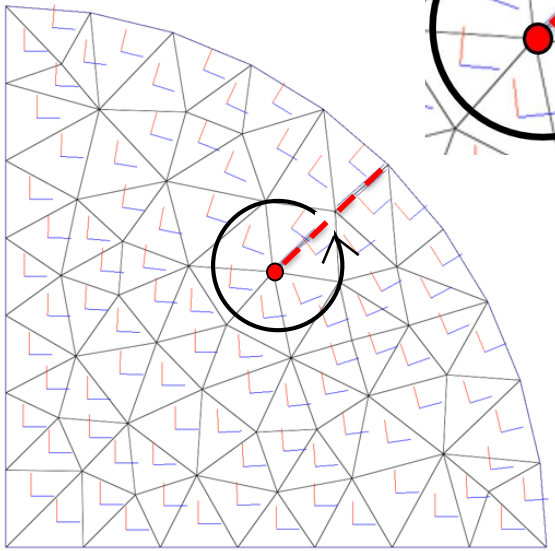
2. Quad computation

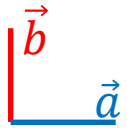
2.1 Extract 2 vector fields





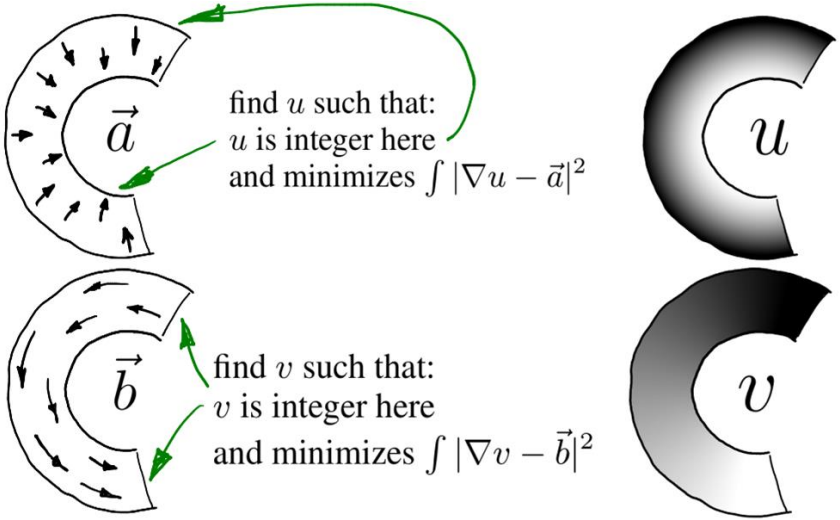


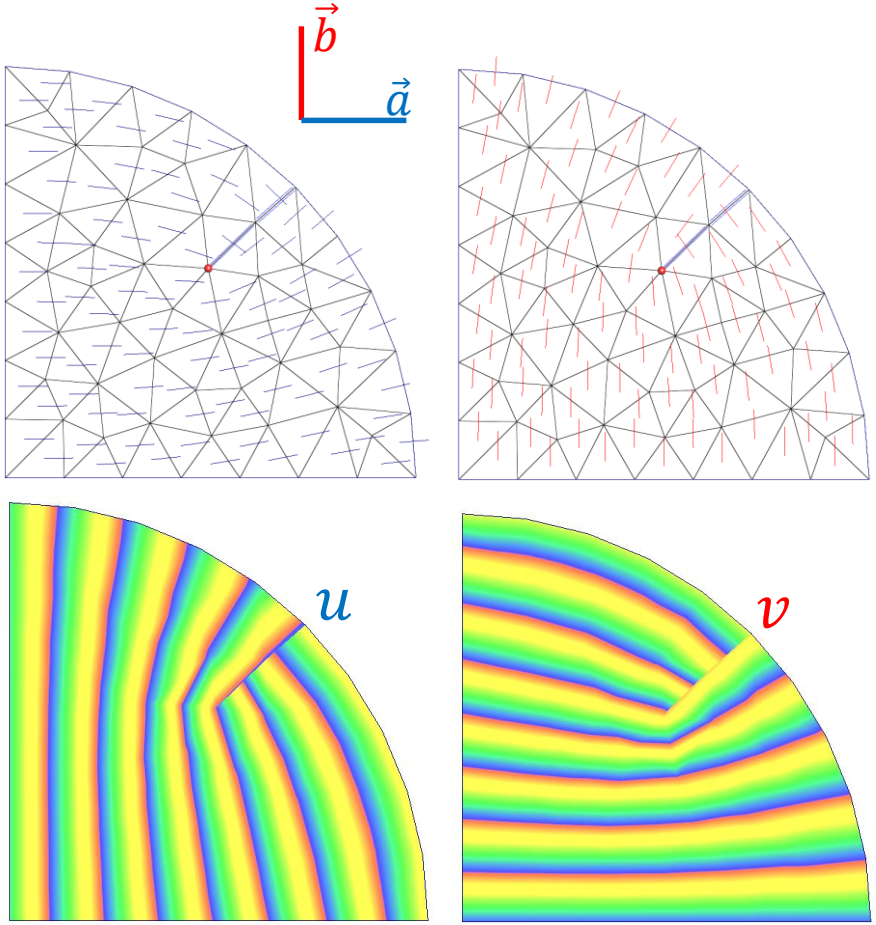




2. Quad computation

2.2 Integration of the 2 vector fields





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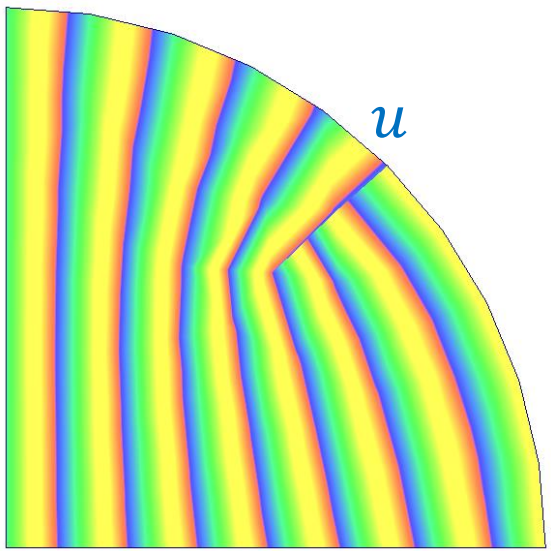
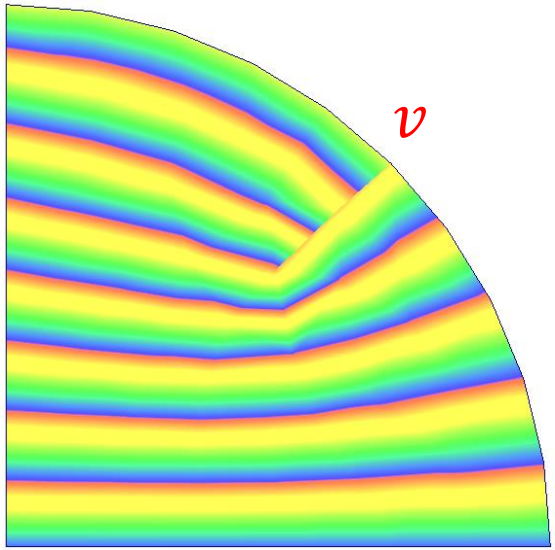
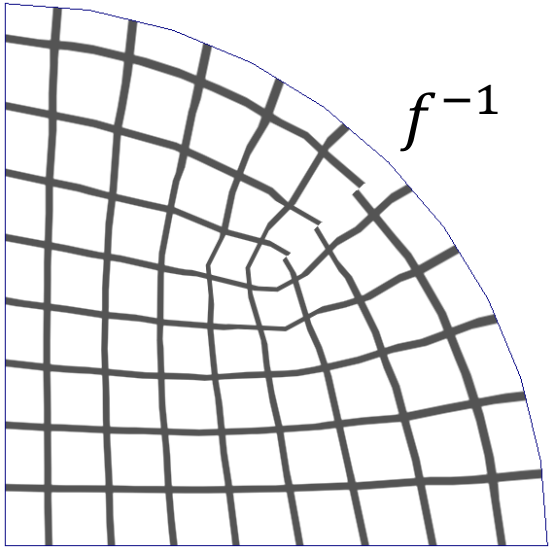


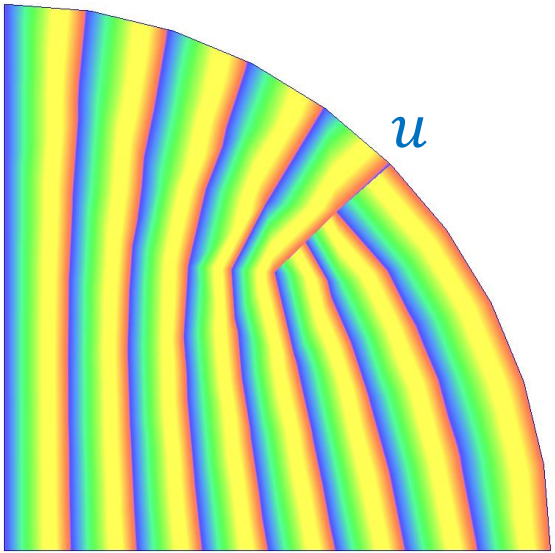


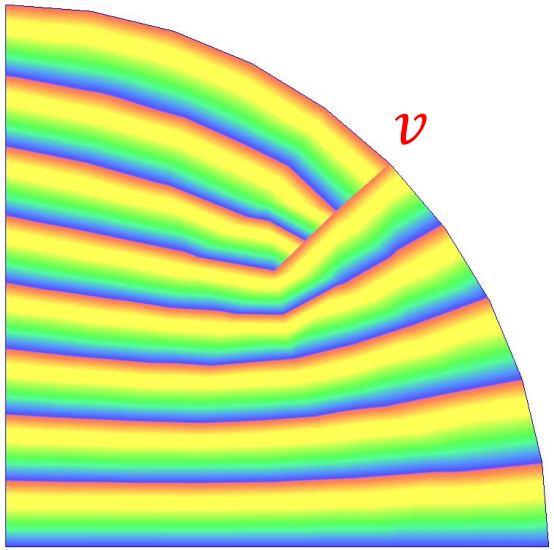


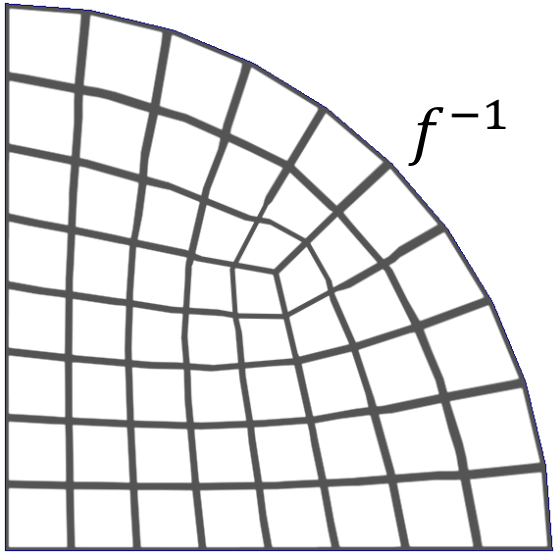
$$f(x,y) = (u(x,y), v(x,y))$$

2. Quad computation

2.3 Alignment with grid integers





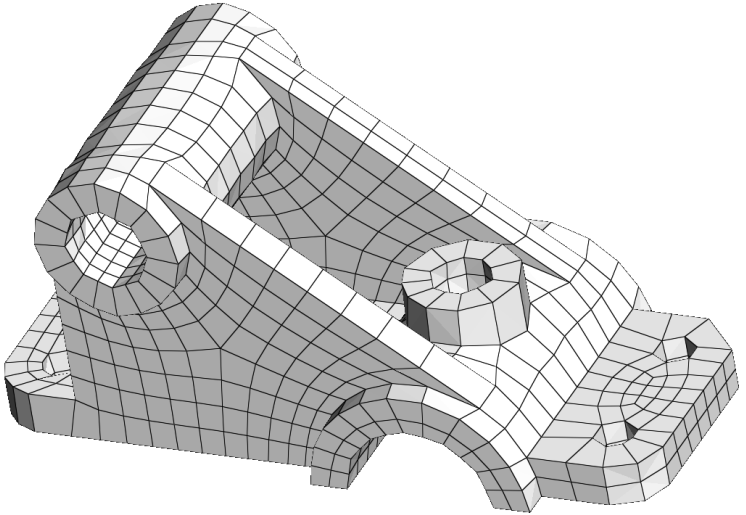


$$f(x,y) = (u(x,y), v(x,y))$$

Meshing results

High quality meshes aligned on boundaries

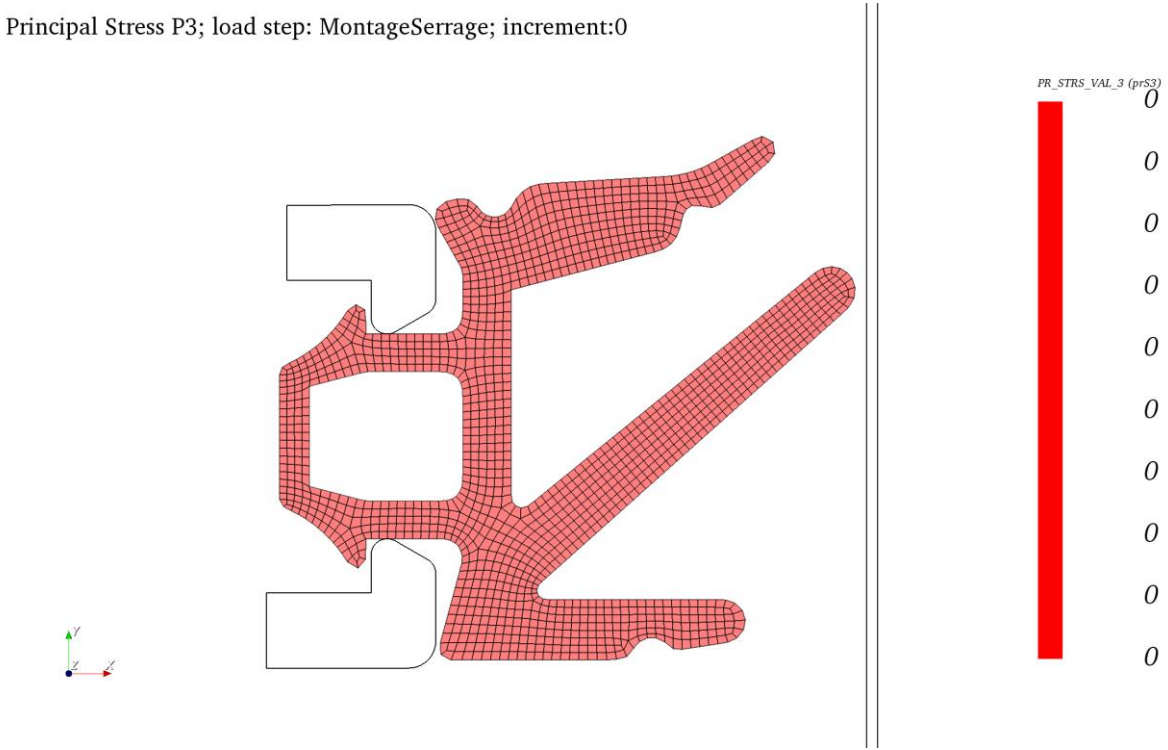
Flat 2D domain



2D domain on the surface of a 3D object

Simulation of large deformations

Solver Numea



Simulation of large deformations

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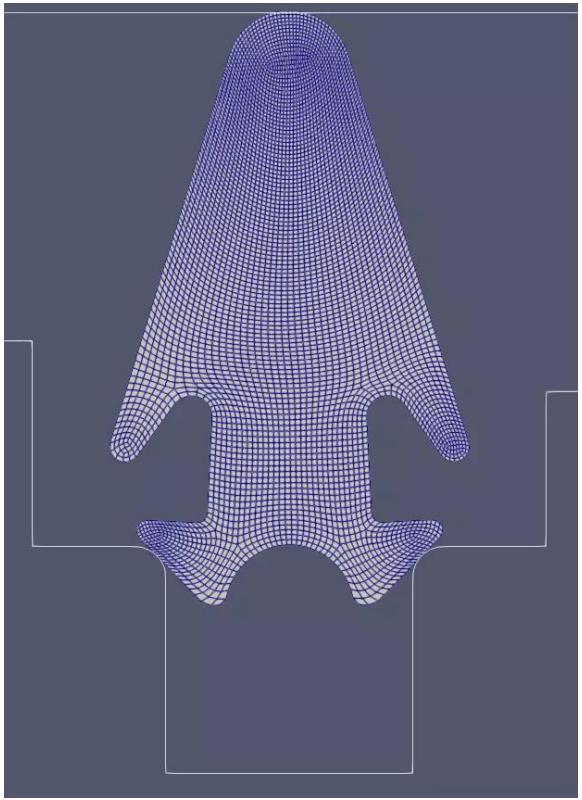
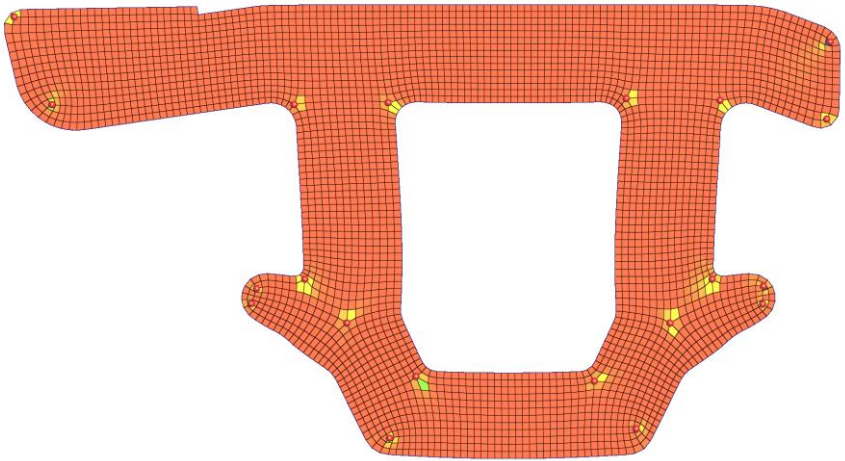
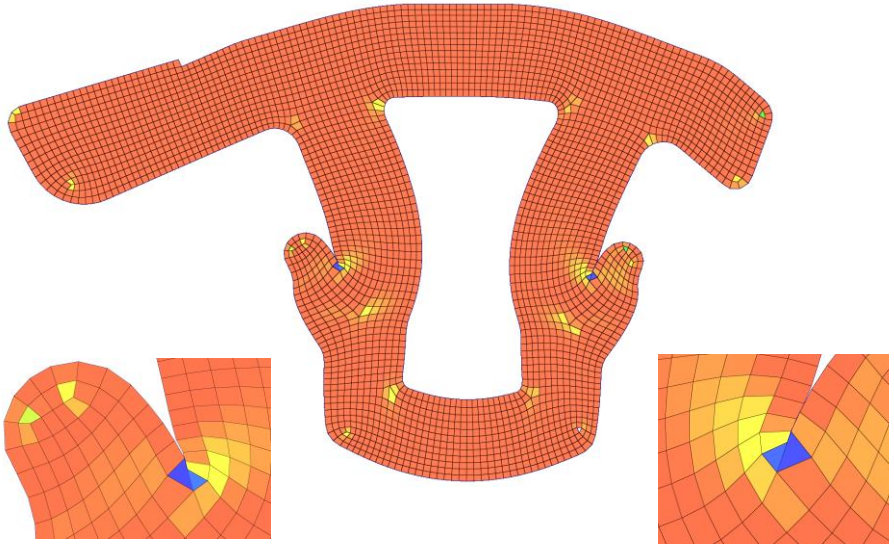


Challenges

Mesh validity through deformation

Invalid cells stop the simulation



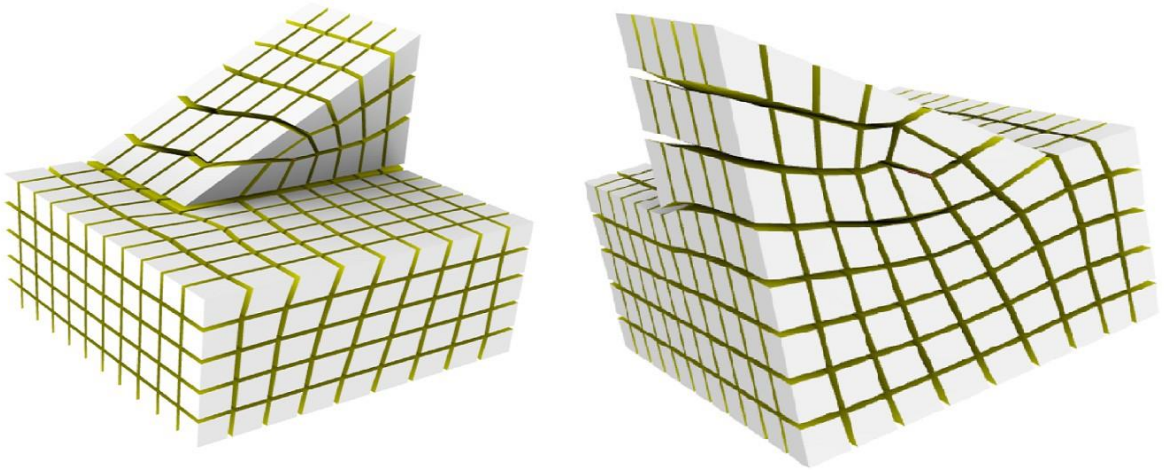


Future work

More user control to set

- Mesh size
- Cell orientation

3D !



Thank you for your attention