HEXOTIC : AN AUTOMATED HEXAHEDRAL MESH GENERATOR

Loïc Maréchal

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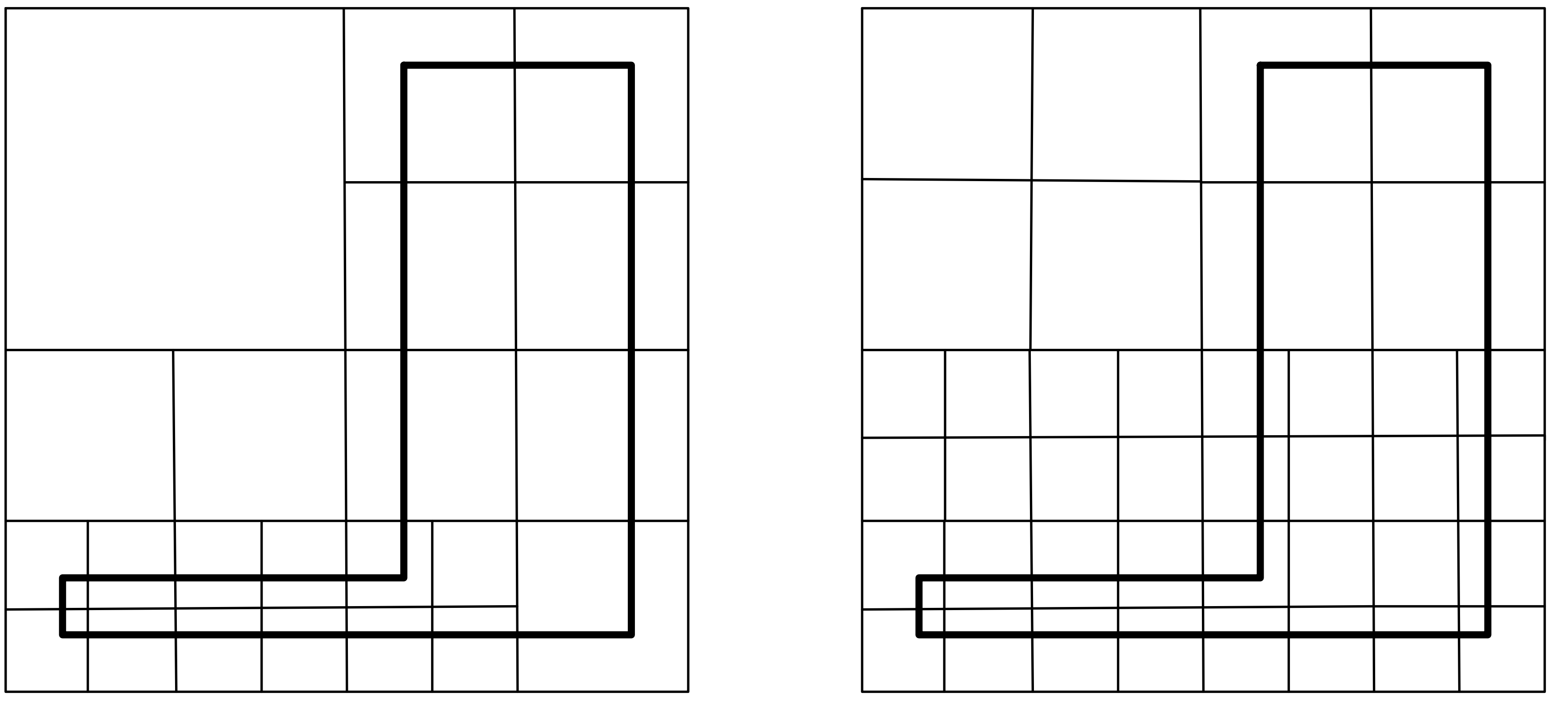
1 / Basics of octree meshing :

-Set of subdivision criteria : geometry's thickness, curvature, a posteriori error estimate.
-Balancing rule : a cell should not be more than two time bigger or smaller than it neighbors.
-Pairing rule : if a cell is to be subdivided, then it "brothers" should be subdivided too.



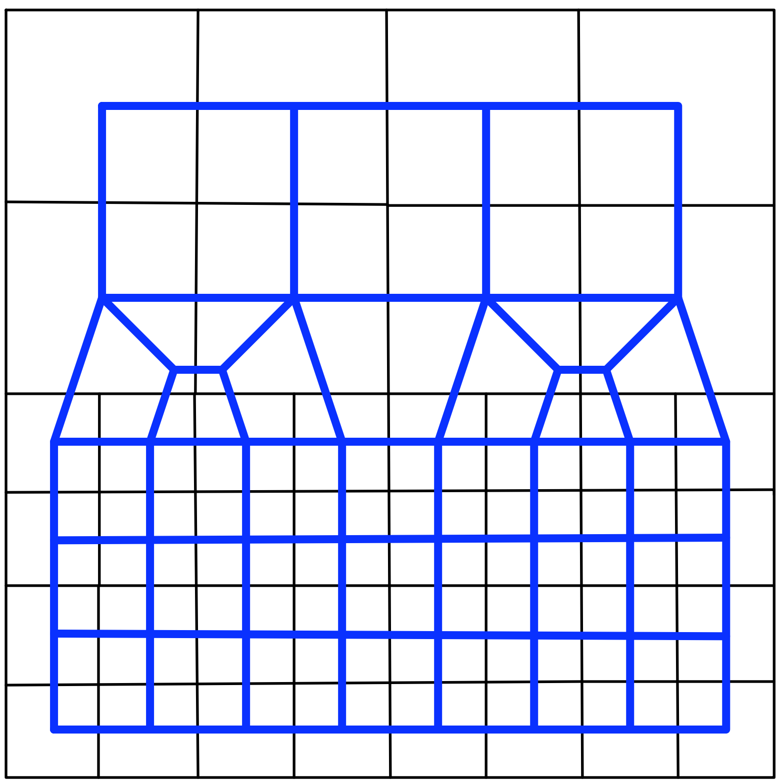
2 / Dual mesh :

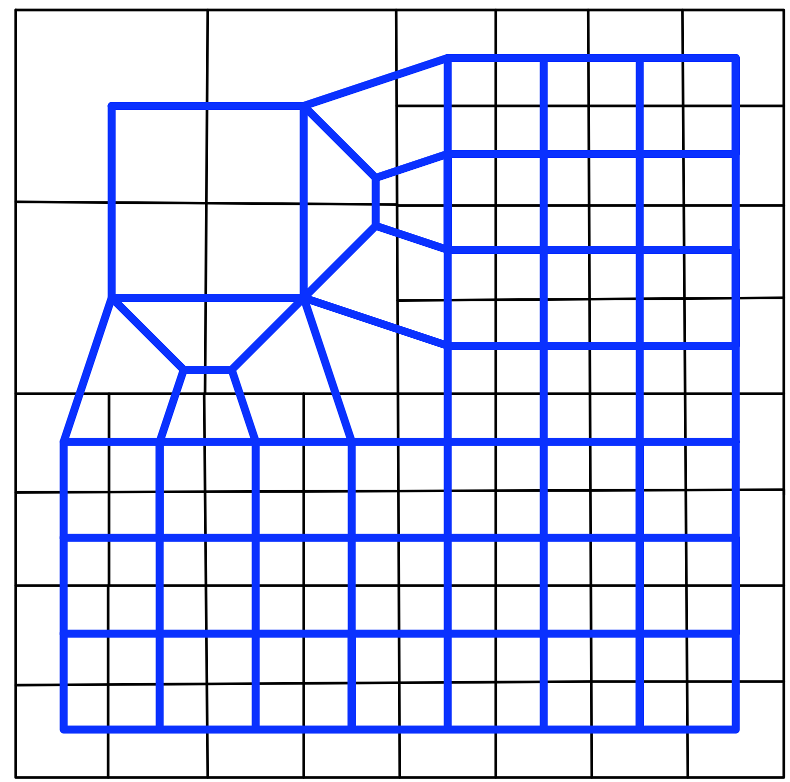
2D :

- element <-> node
- edge <-> edge

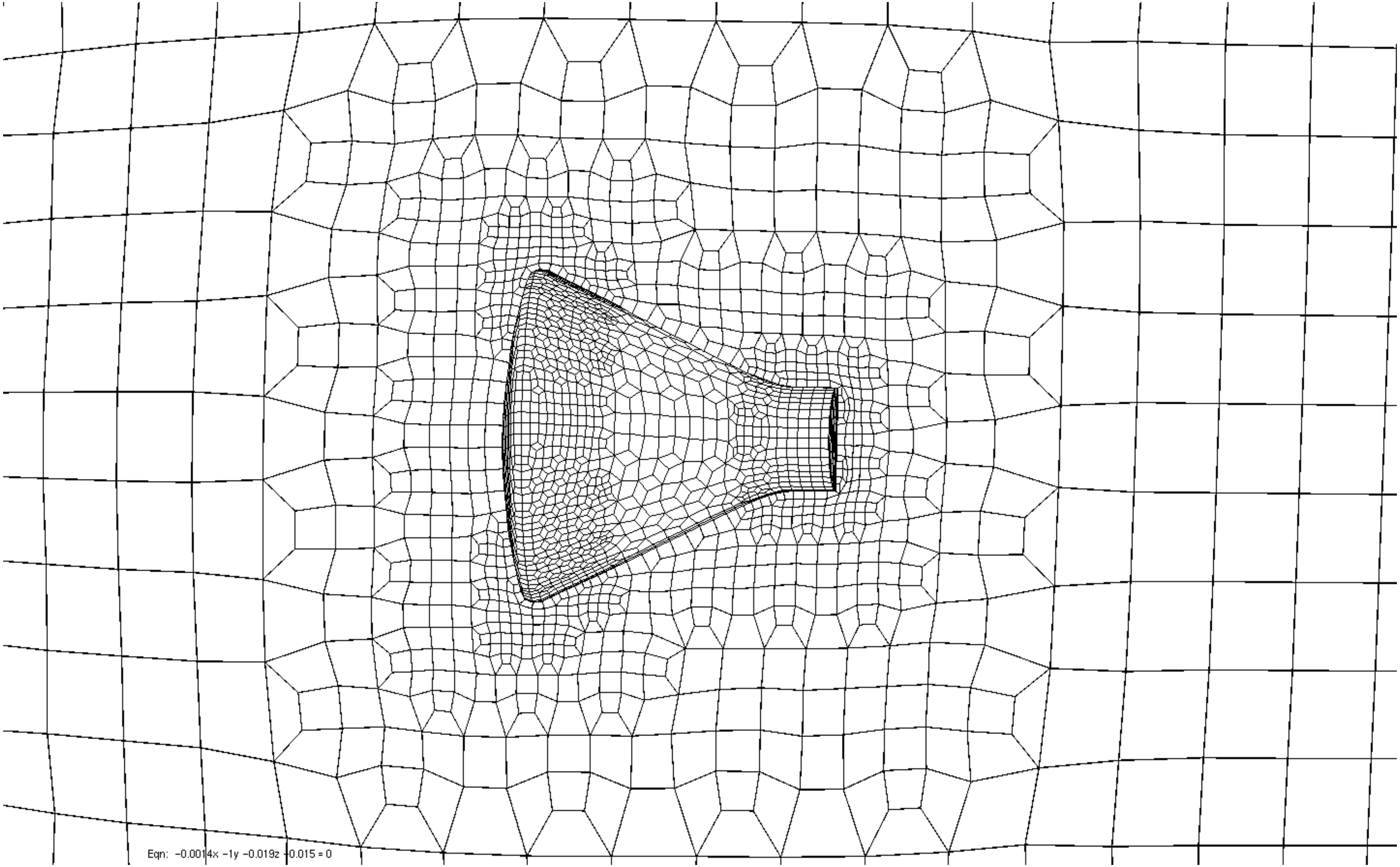
3D :

- element <-> node
- face <-> edge





2b / Dual mesh :

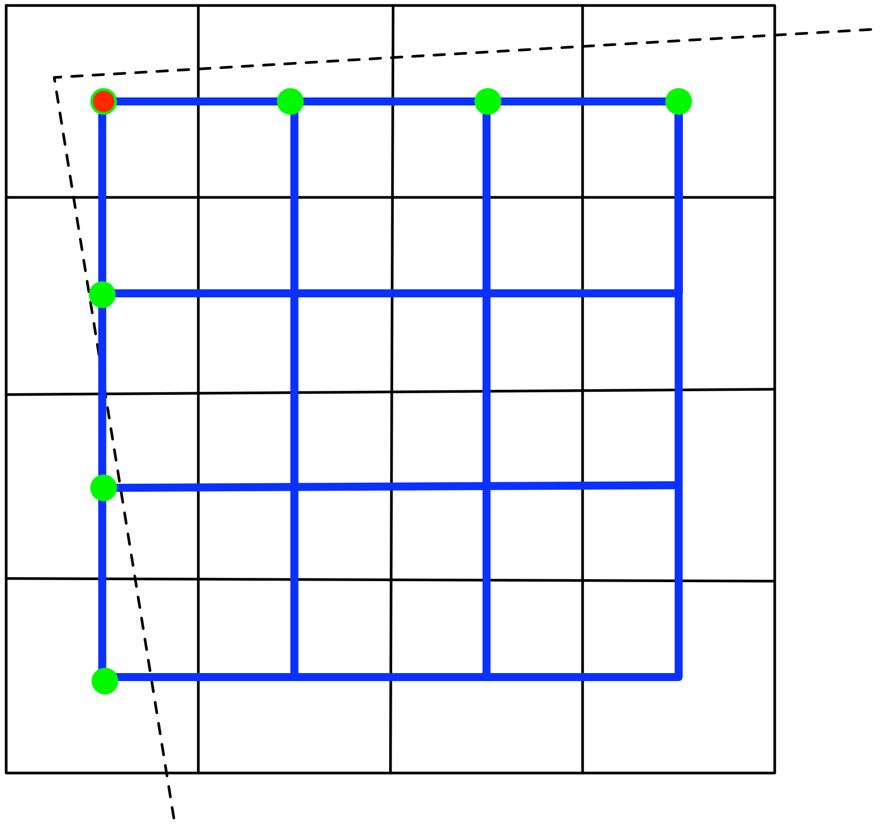


3 / Surface meshing :

Analysis of edges (triangles) intersecting each octant :

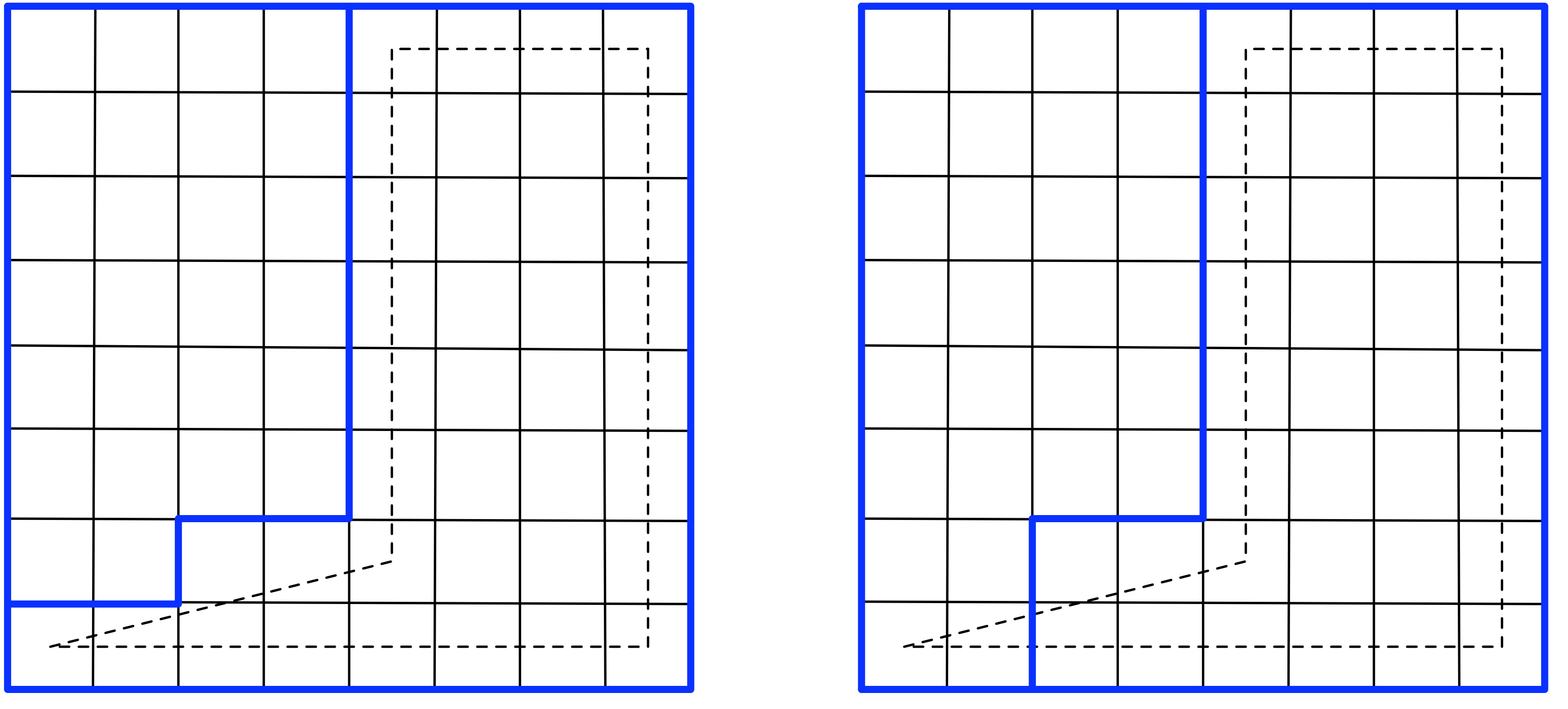
2D :
1 group -> median line.
2 groups -> two intersecting lines
   making a sharp angle.
3+ too complex.

3D :
1 group -> median plane.
2 groups -> two intersecting planes
   making a sharp edge.
3 groups -> three intersecting planes
   making a sharp corner.
4+ too complex.



4 / Subdomain recovering :

-Basic inside/outside algorithm.
-It can handle internal surfaces (non-manifold geometries).
-Domains must be two-element thick in any direction.



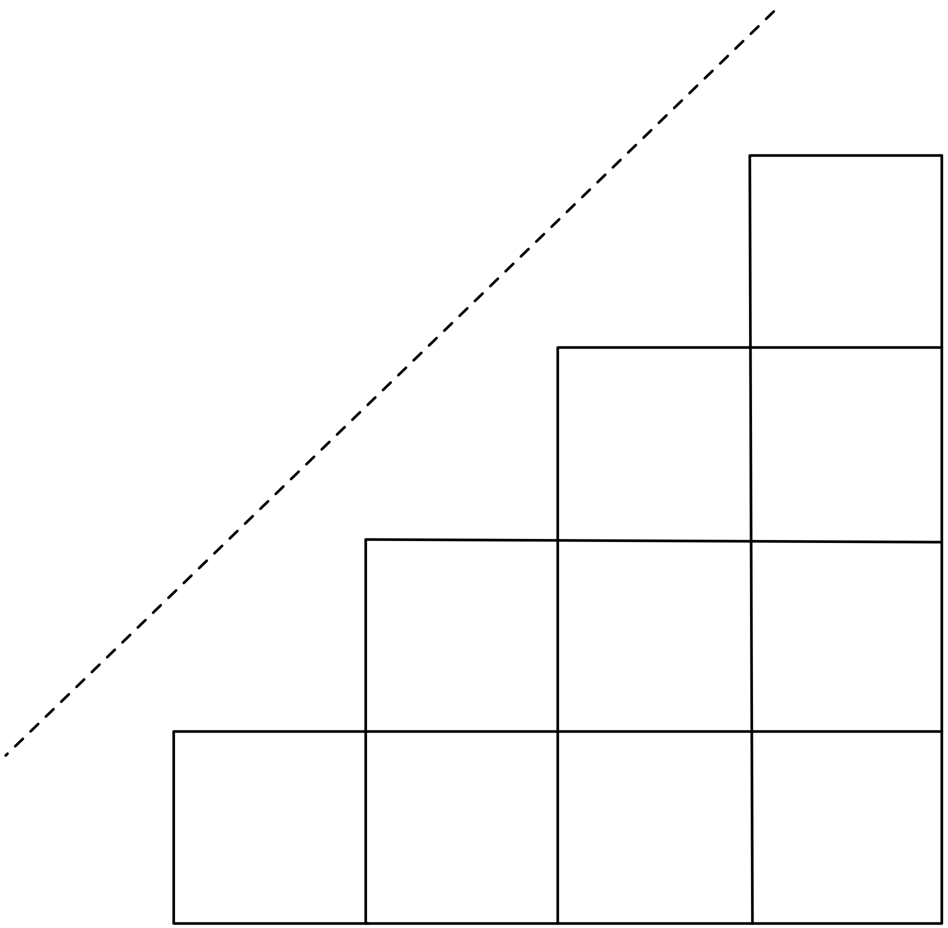
5 / Surface projection :

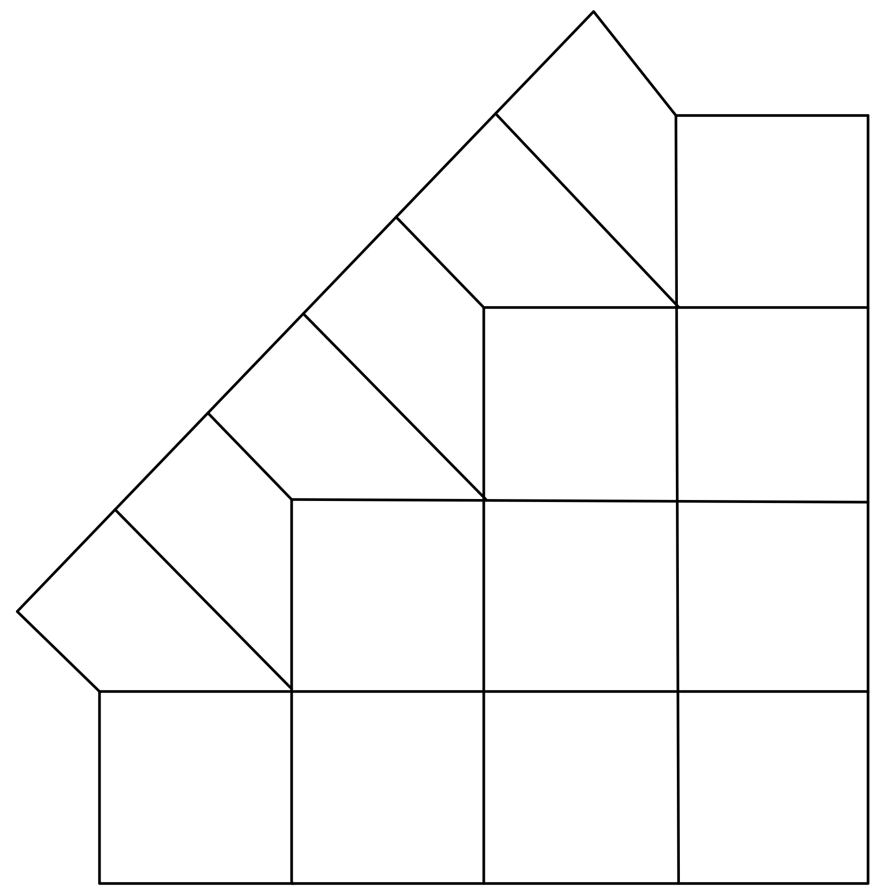
Problem : octree generates a so called "staircase mesh".

-Hexes may have two or three faces to be projected on the same plane -> degenerated.
-Surface quad may have two edges to be projected on the same sharp line.

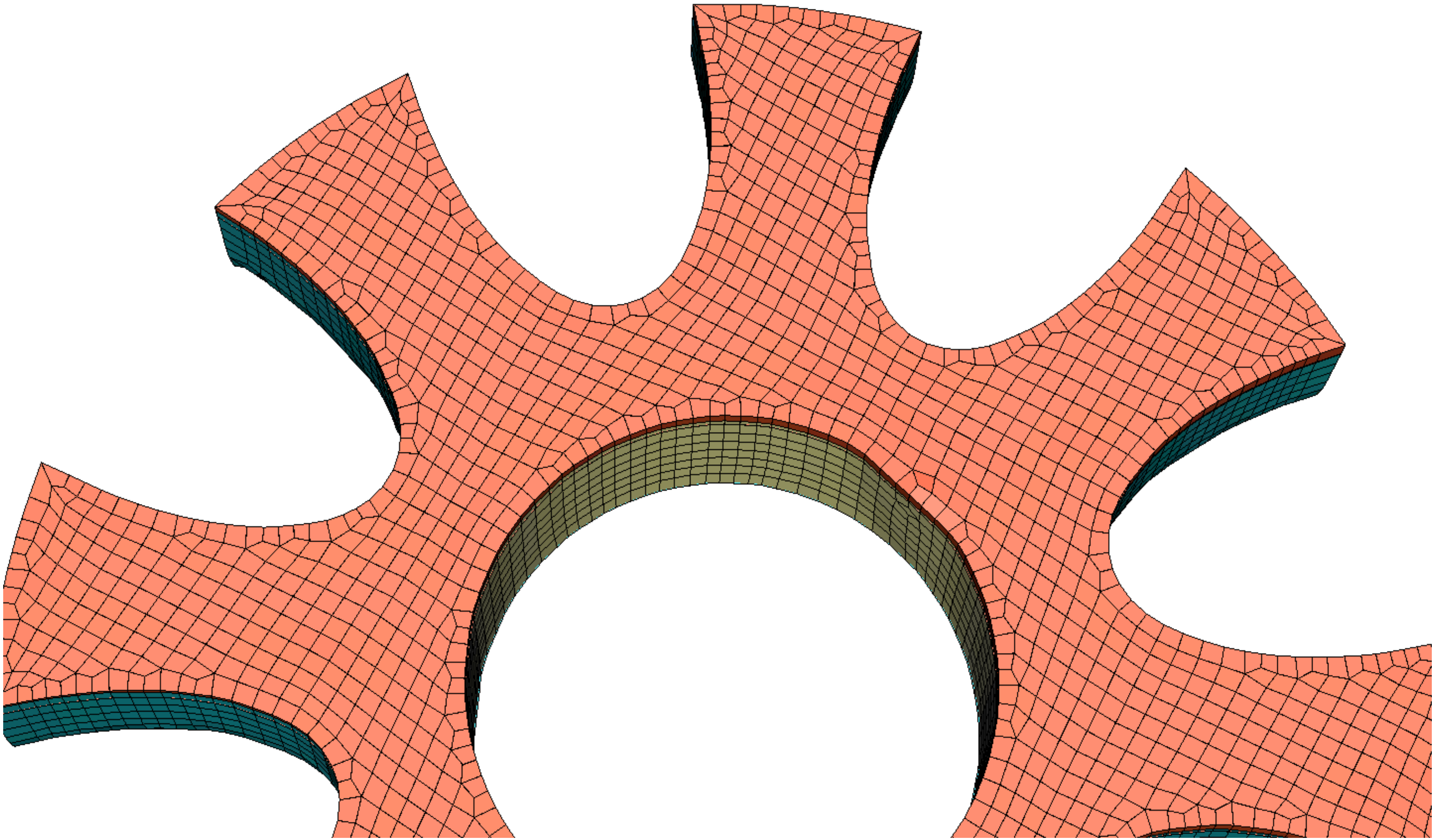
Solution : buffer-layer insertion

-A first layer of hexes is inserted around the staircase mesh so that new boundary elements have only one face to be projected on the real geometry.
-Likewise, a second layer of element is inserted around sharp edges.

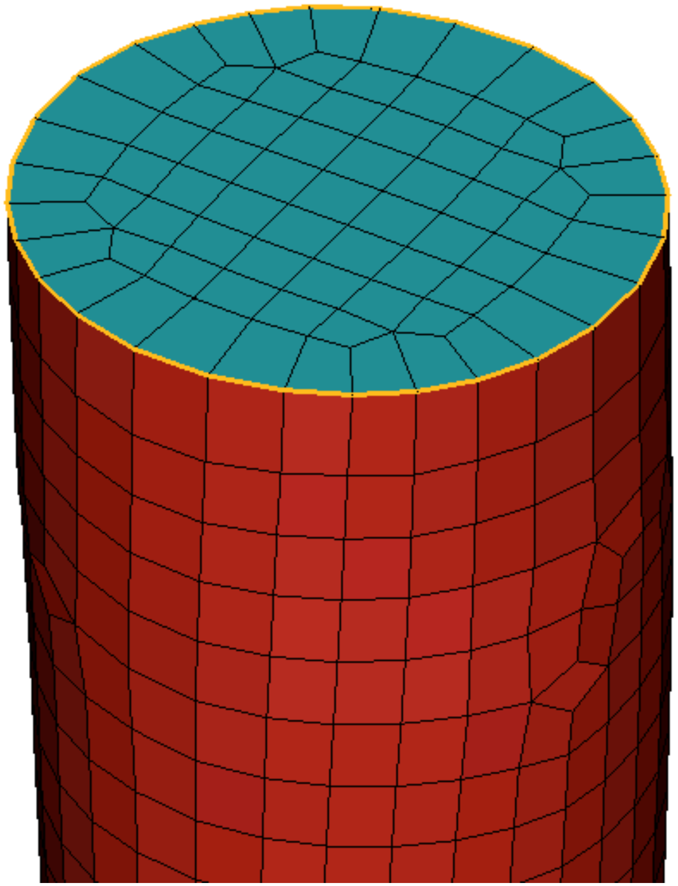


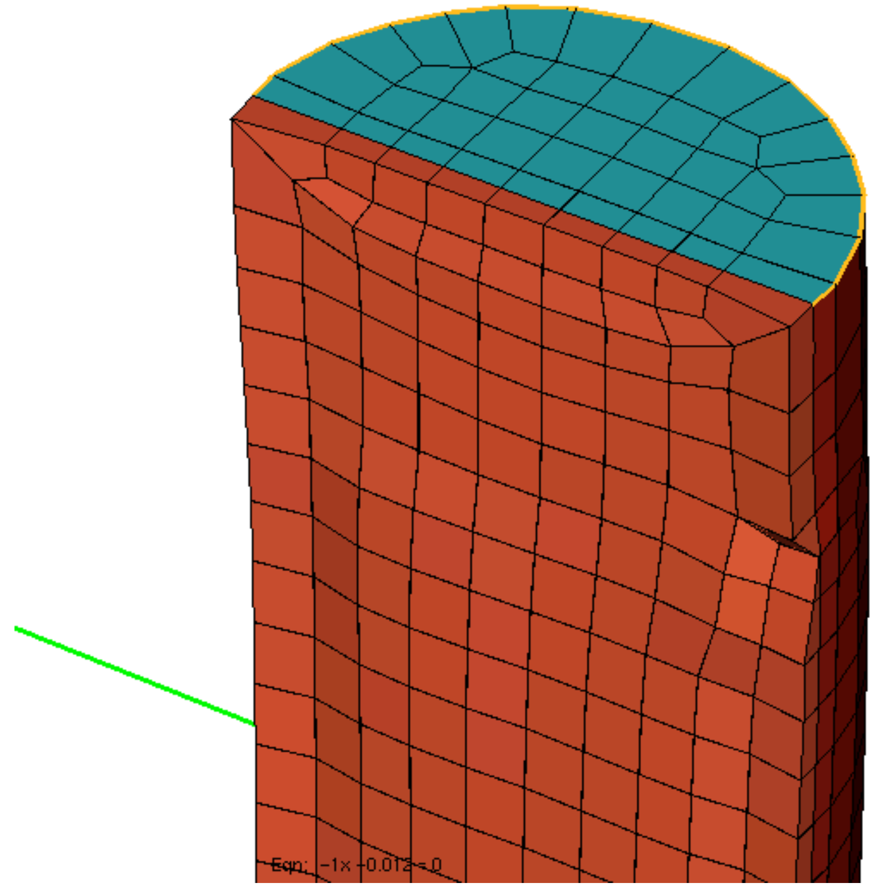


5b / Boundary after projection :



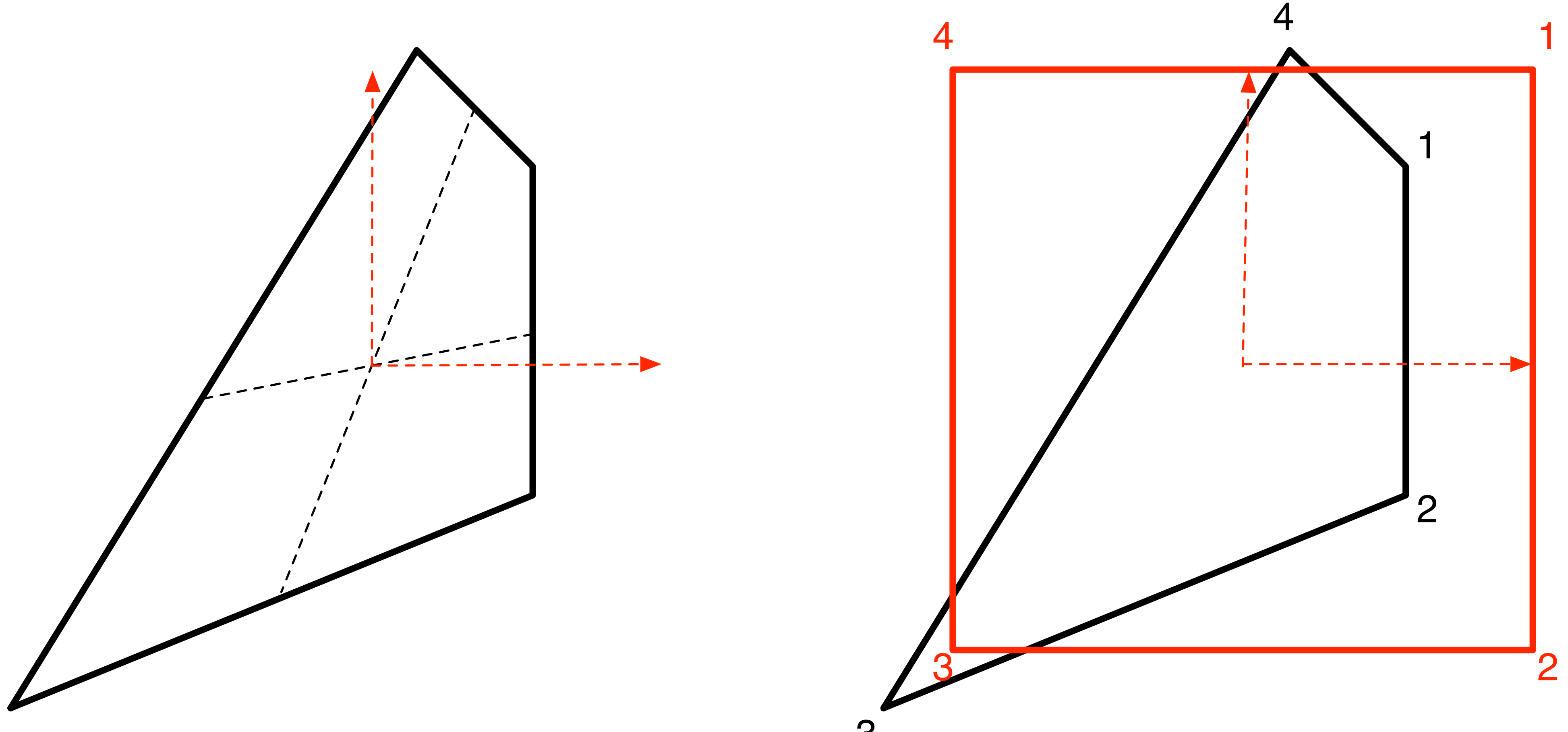
5c / Second layer :





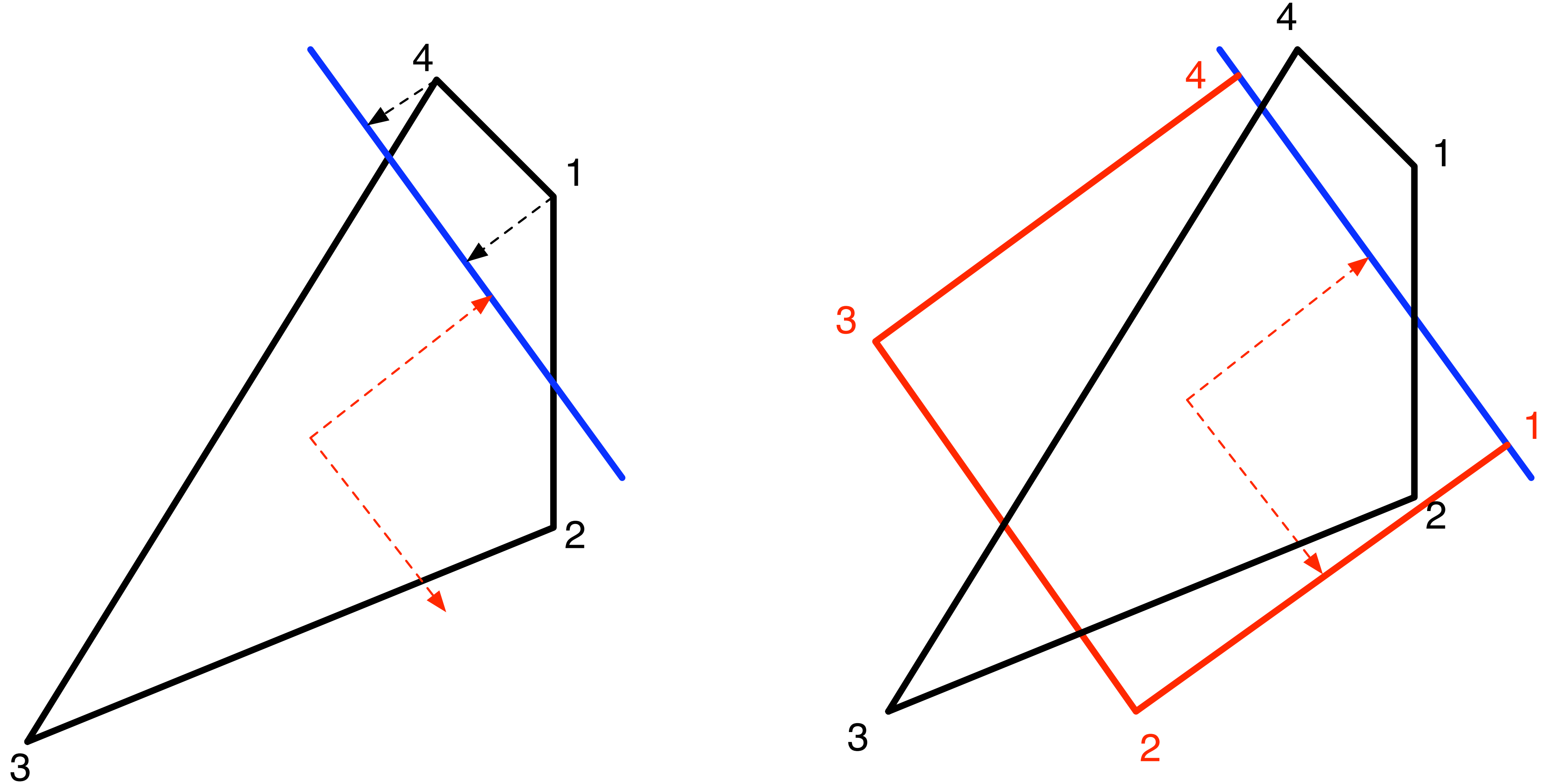
6 / Quality optimization via node smoothing :

- -Each solver has its own quality criterion.
- -Only one common ground : each hex must have a positive volume.
- -So we can only try to get as close as possible to the perfect cube.
- -The optimizing process finds the closest perfect cube from each hex and adds the contributions to a new set of nodes' coordinates which eventually will result in a better mesh.

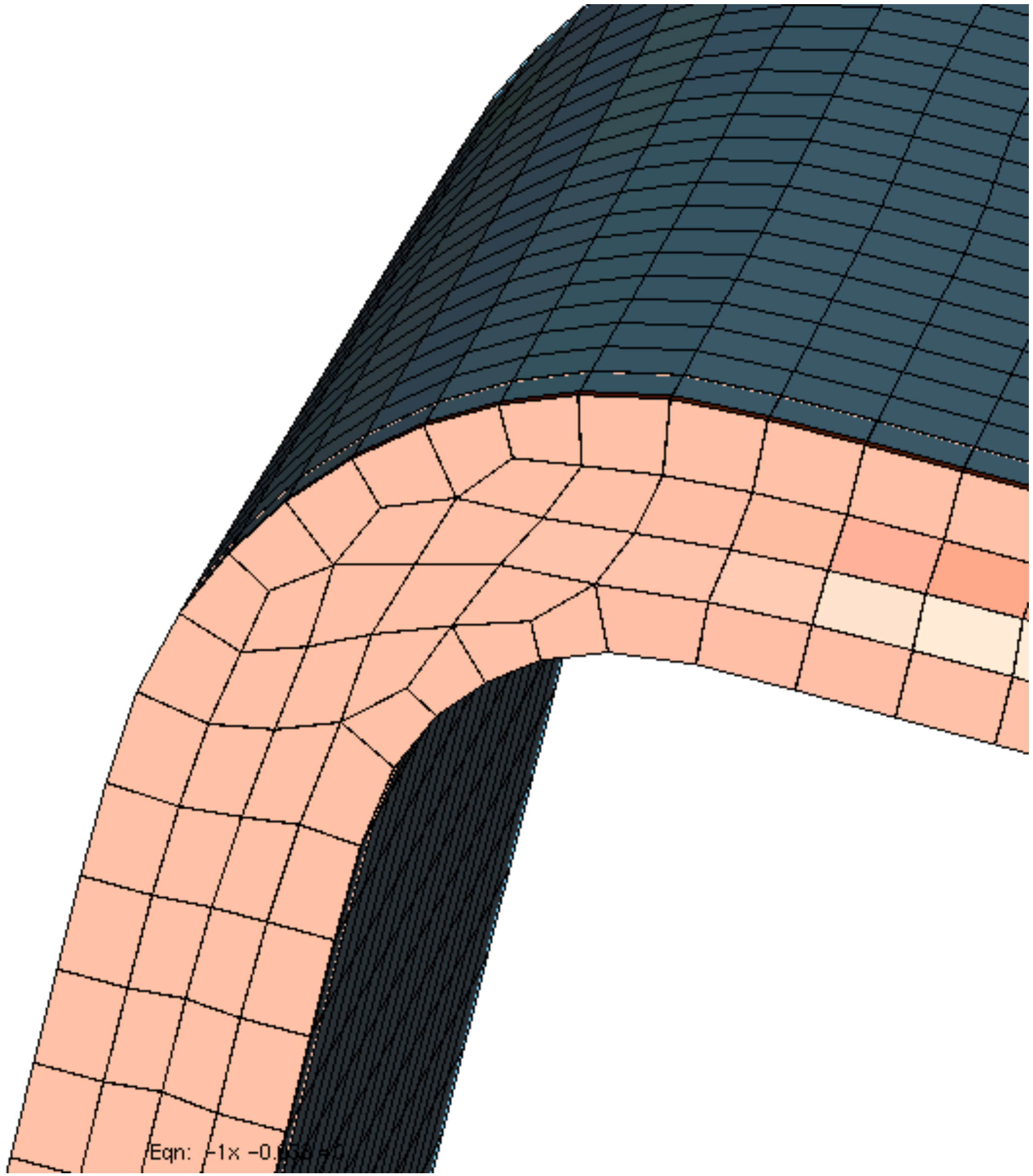


7 / Boundary constrained optimization scheme :

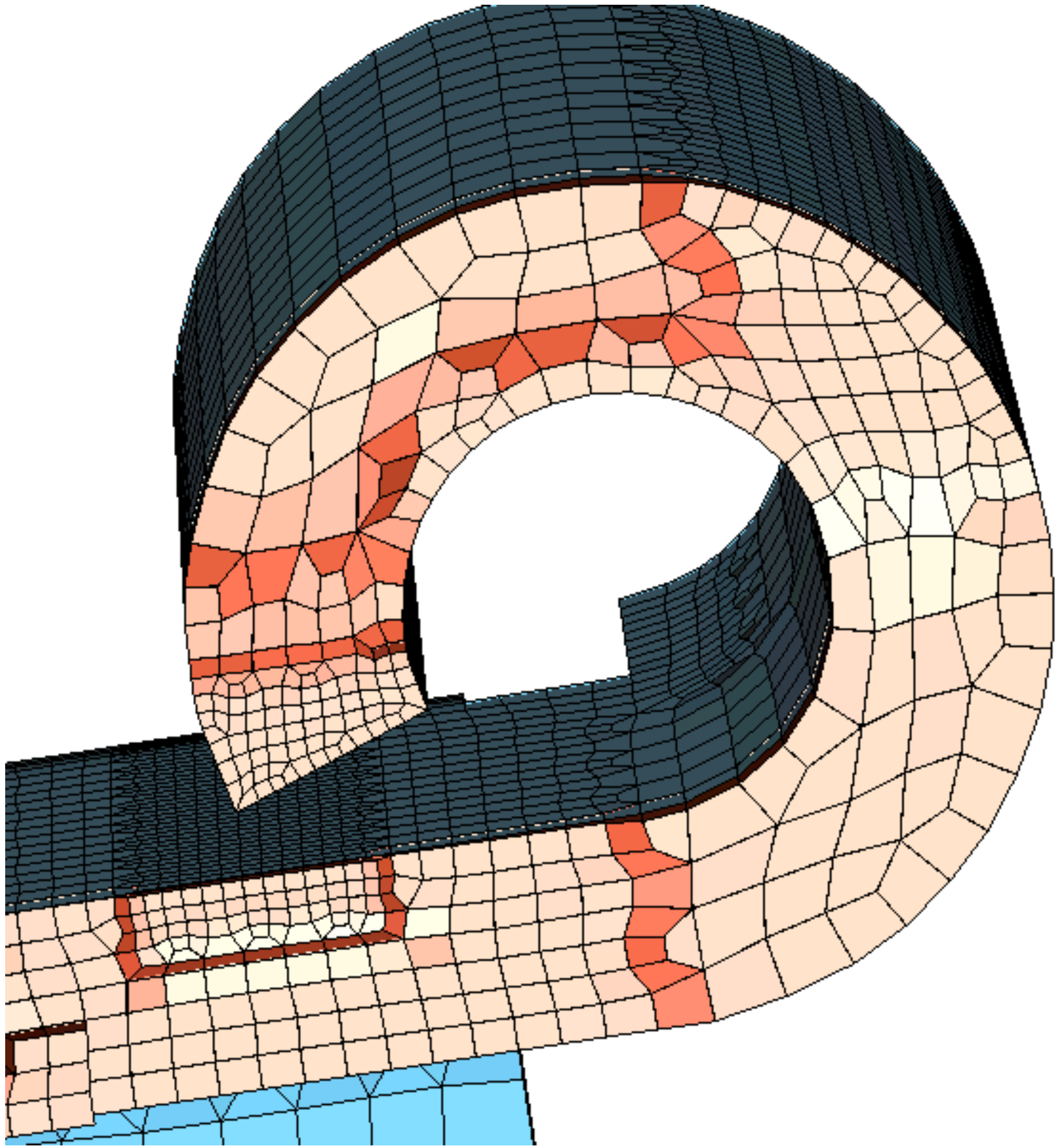
- -Boundary elements could be treated the same way as others and surface node could be projected on the geometry afterward -> interlocking : smoothing may move nodes in one direction and projection may move them back !
- -Geometry should be part of the smoothing scheme : the perfect cube is rotated and pushed away so that its surface face matches the geometry it should represent.



8 / Strong limitation : he lack of topological operators on hex meshes :

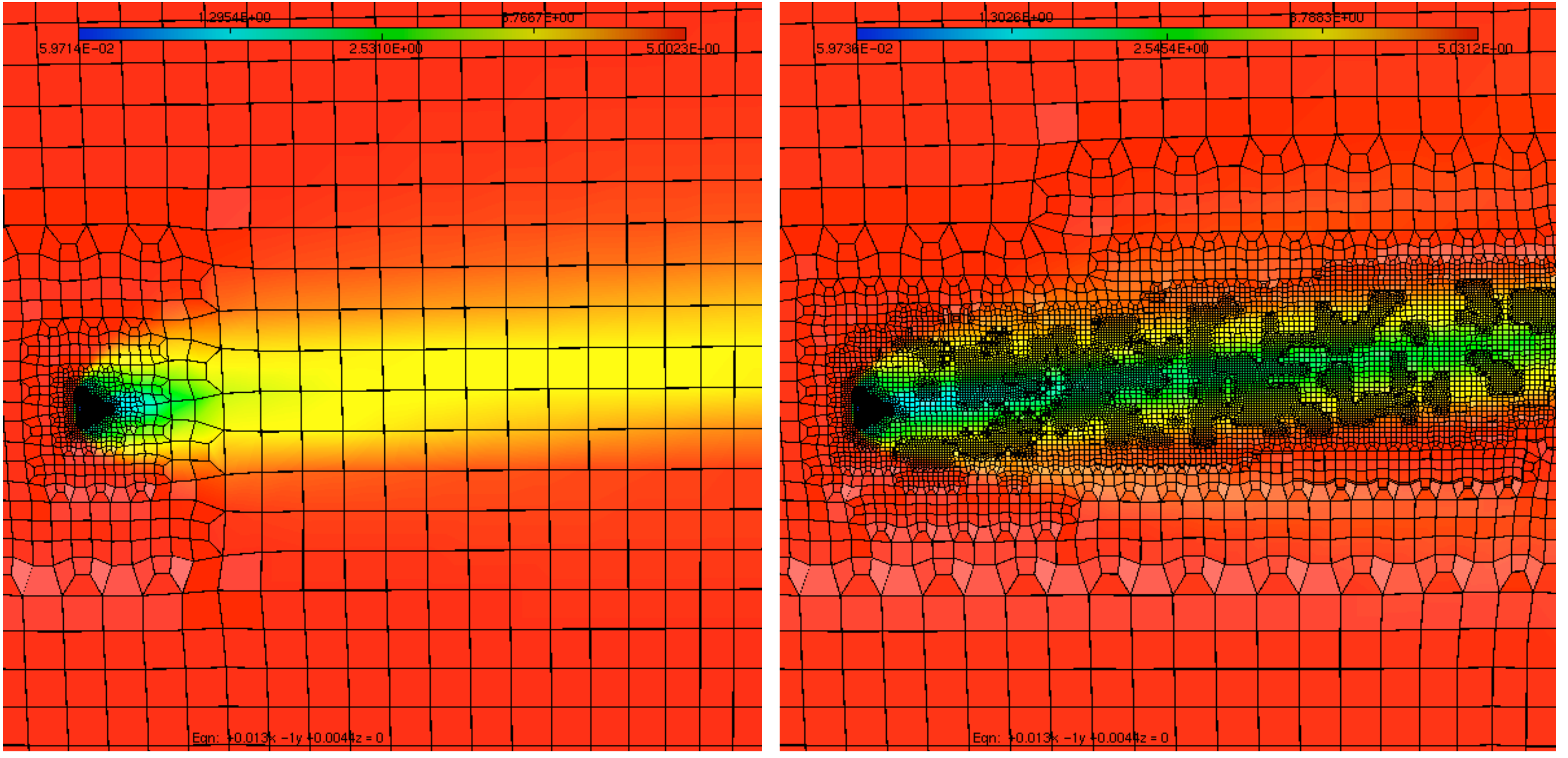


8b / Strong limitation : the lack of topological operators on hex meshes :

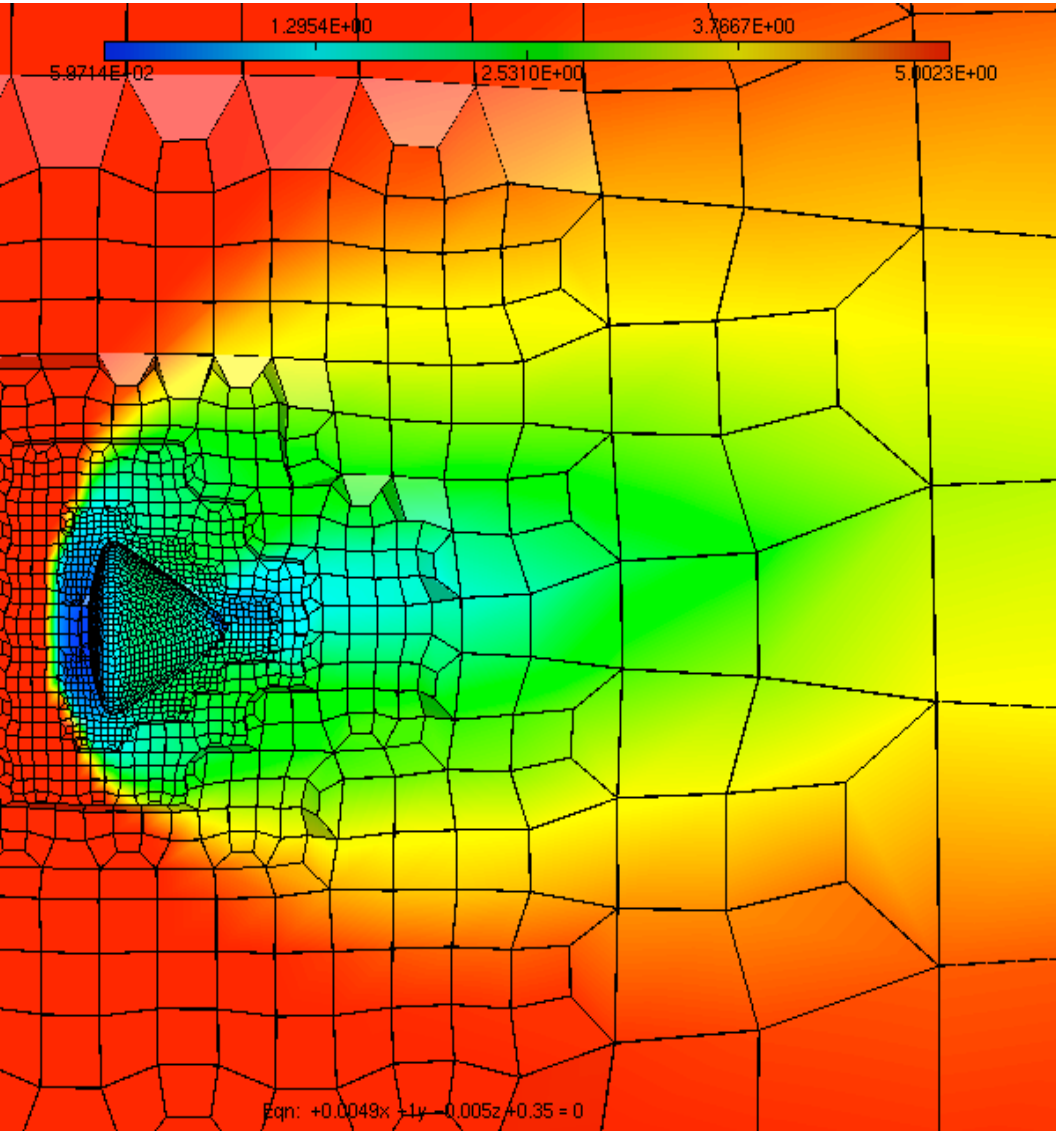


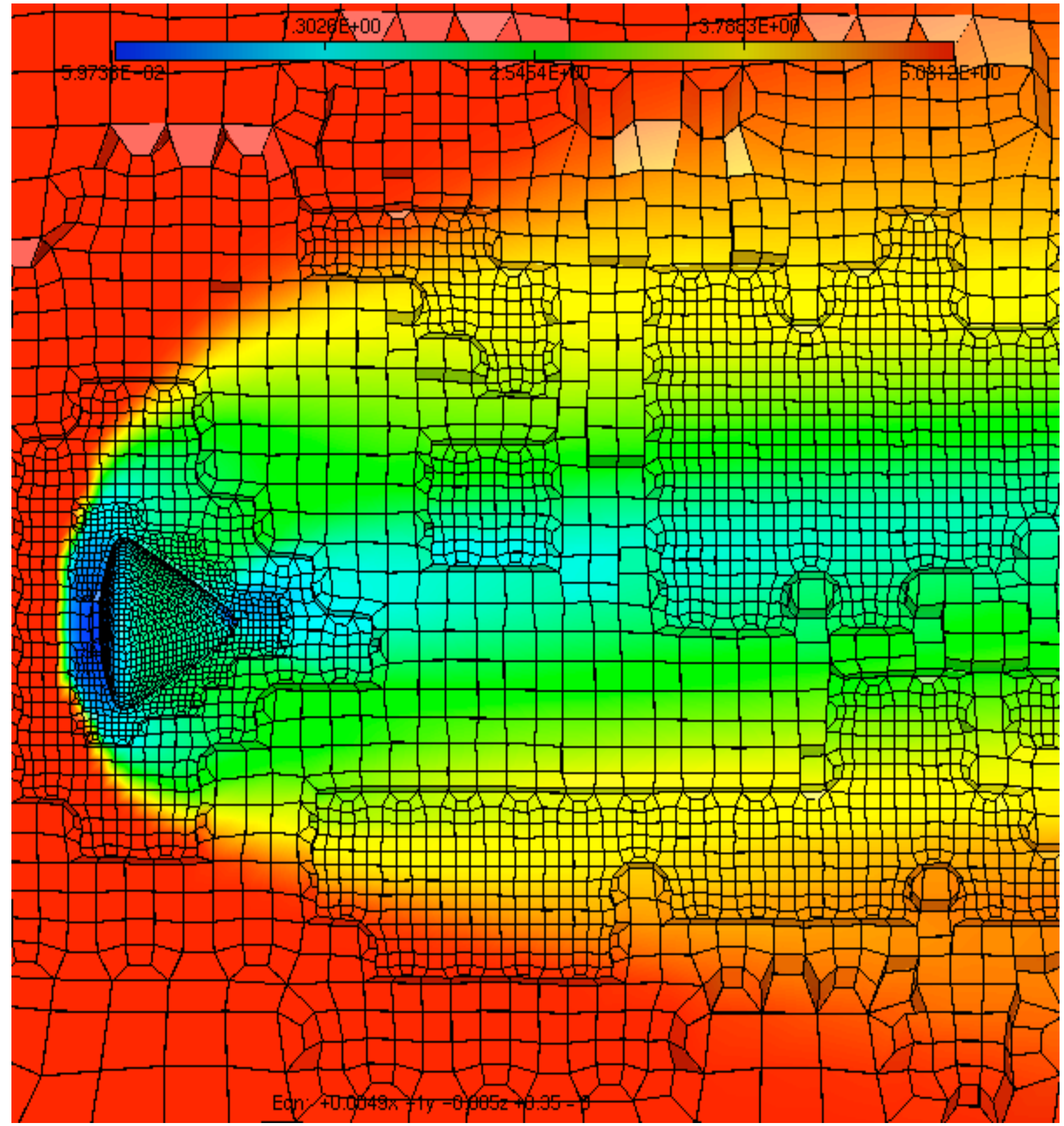
9 / Mesh adaptation :

-Only isotropic adaptation because of the octree method : no anisotropy like in tet meshes.
-Twofold size ratio between neighboring elements : no smooth size transitions.

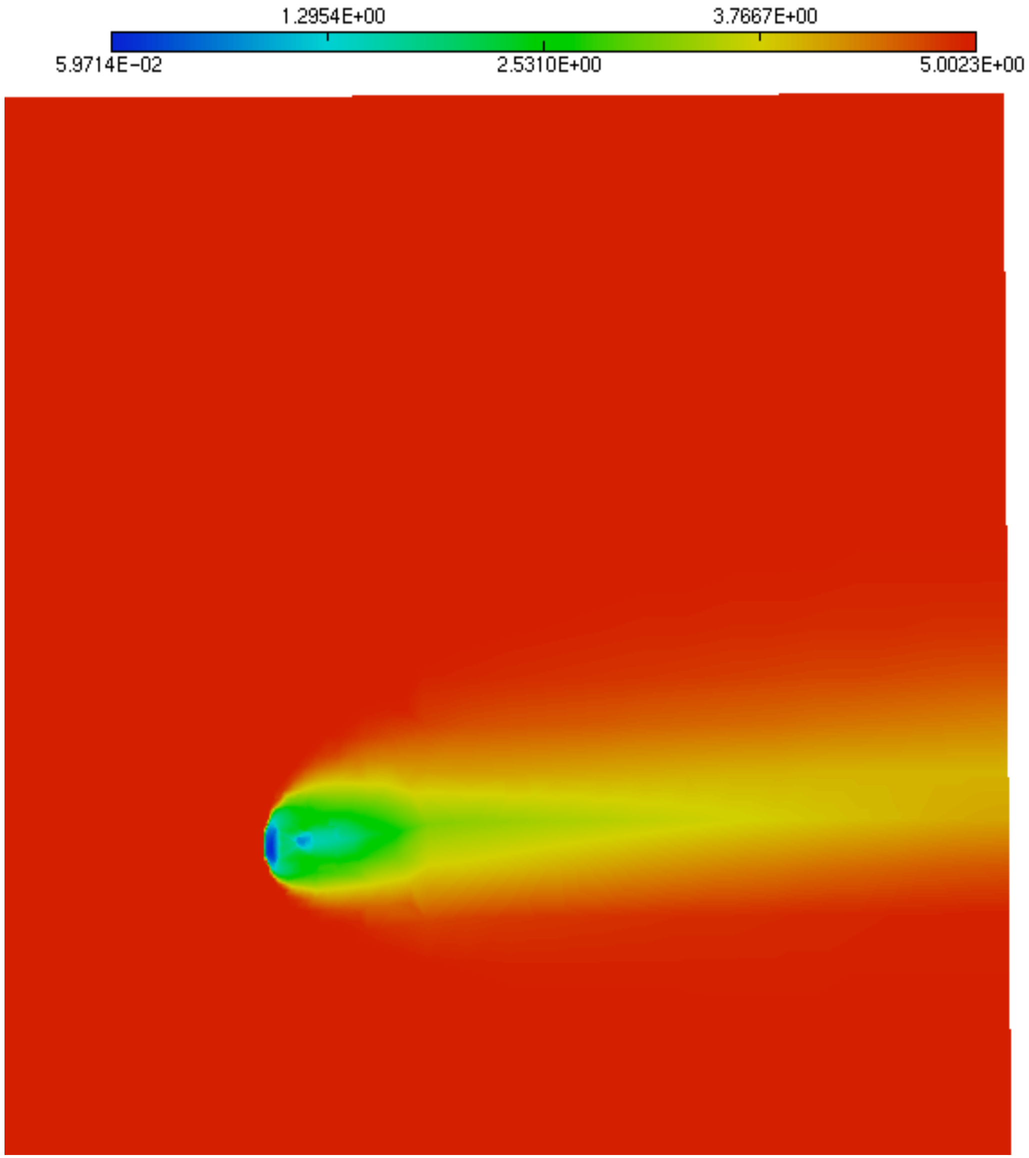


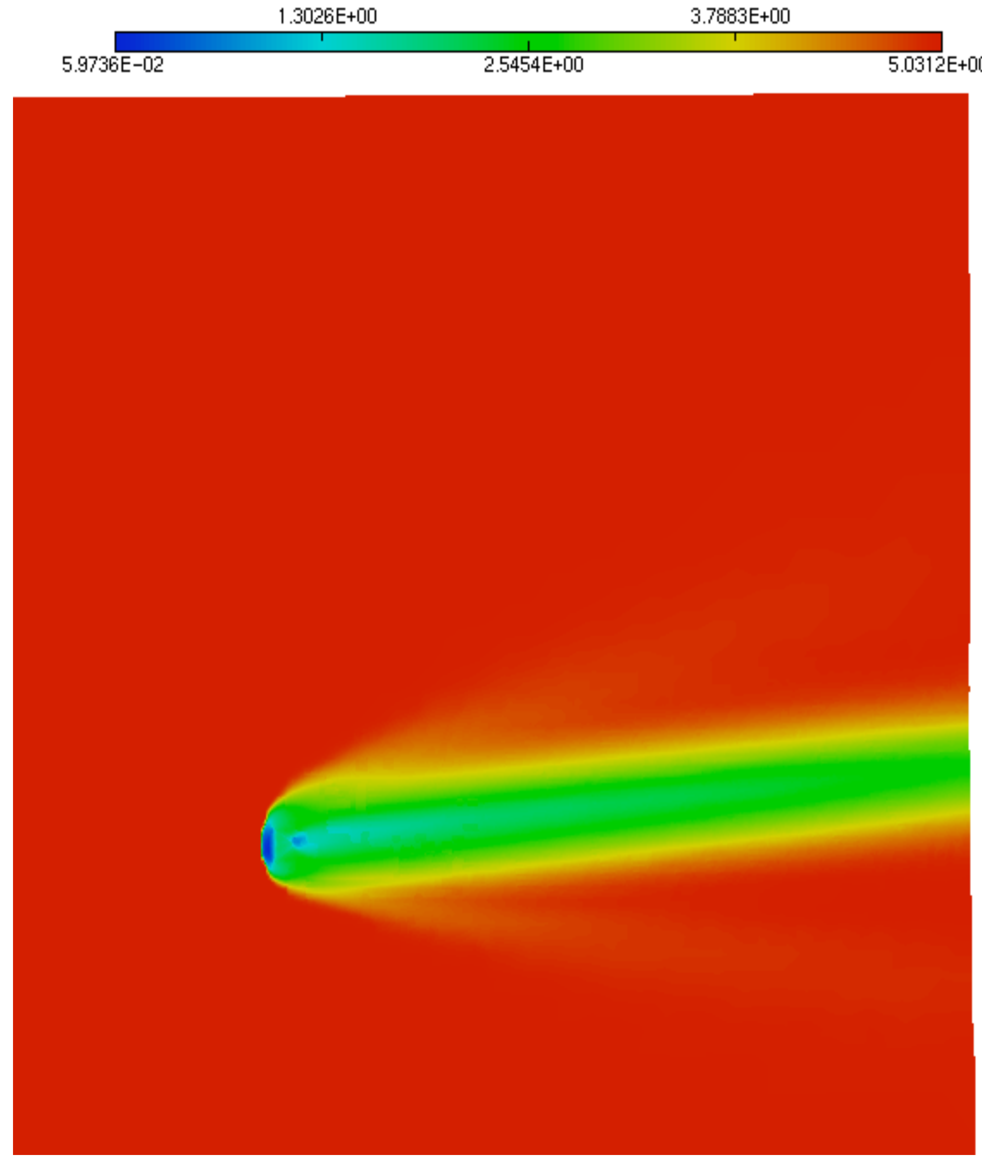
9b / Mesh adaptation : the apollo capsule





9c / Mesh adaptation : the apollo capsule





10 / Plus and Minuses of this method :

+ Robust : it always produces a result (but it may not be the meshed you dreamed of...)
+ Fast : 2.000.000 elements / minute on this laptop.
+ Simple : command-line program requiring few arguments (min,max sizes, sharp angle threshold)
+ 100 % hexahedral and conformal meshes (no pyramids, prisms or hanging nodes).

-Generates too many elements when it comes to thin geometries (blades, wings, etc...)
-Isotropic meshing only.
-Present version cannot handle very sharp angles : hexes gets too distorted.
-Unstructured meshes (although larger parts of meshes are grid-like).

Work is under way to limit the number of elements in thin geometries via a hybrid method using octree in thick parts and surface extrusion in thin ones.
This method will also allows for more accurate meshing of very sharp angles.

Conclusion : there is still a long way to go to reach the "holly grail" of hex meshing !