The Marching Tetra Method for Full Vehicle Meshing

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Target

Create an adaptive and conformal mesh for 10 000 parts, accept any part.
Perform Boolean subtract for overlapping parts.
Mark the imprints (= common surface of two parts)
The element quality should be good.

Input

Stl data of 10 000 parts: watertight triangular surface representation,
+ 4 parameters: Initial edge size, maximum number of refinements, feature angle and minimum element quality

Output

For all parts: Tetra mesh and surface mesh with imprint information “this part is in contact with part xxx”. Fluid mesh.

Marching Tria / Quad / Tetra / Cube methods

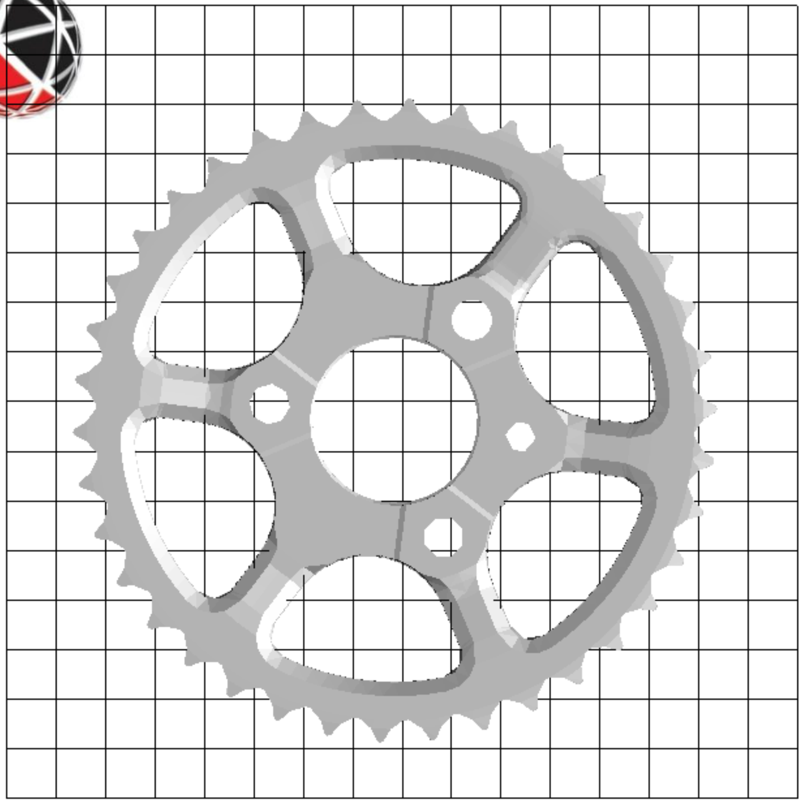
Marching Cube: 1987 by Lorensen and Cline for CT-segmentation Problems.

Multigrid Methods for fast PDE solvers: Hackbusch 1980 + … + Bänsch 1986 + .. :
- Create hierarchical subspaces for linear solvers with O(N) performance.
- Create adaptive refinements to compute efficiently.

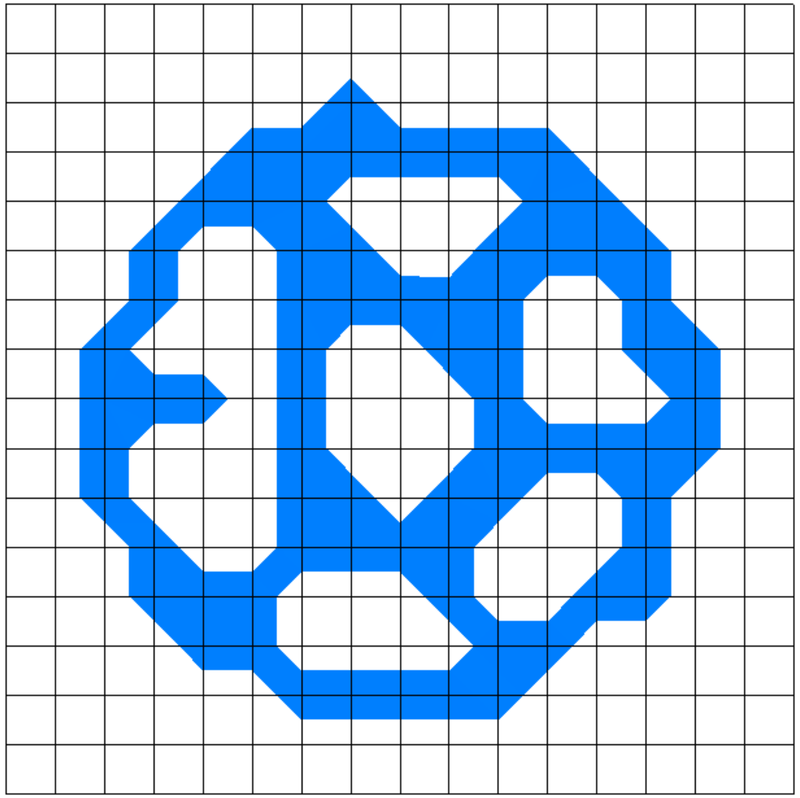
- Create adaptive refinements to approximate geometry ……….

Wikipedia 2019: “Geometric multigrid is too difficult to apply“ (Trottenberg)

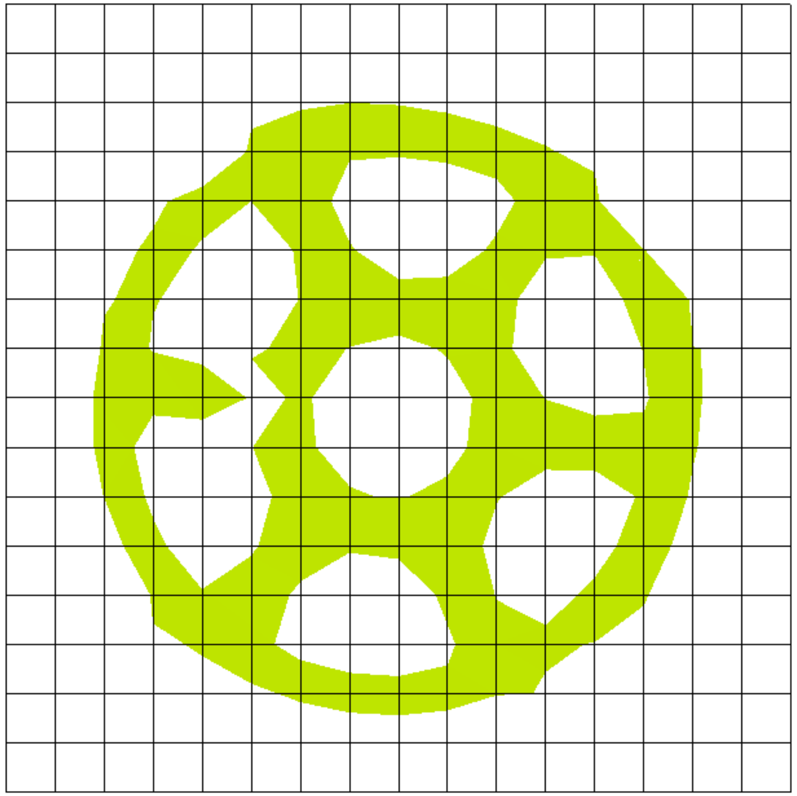
This is not true.



Watertight input geometry
gridpoints inside or outside?



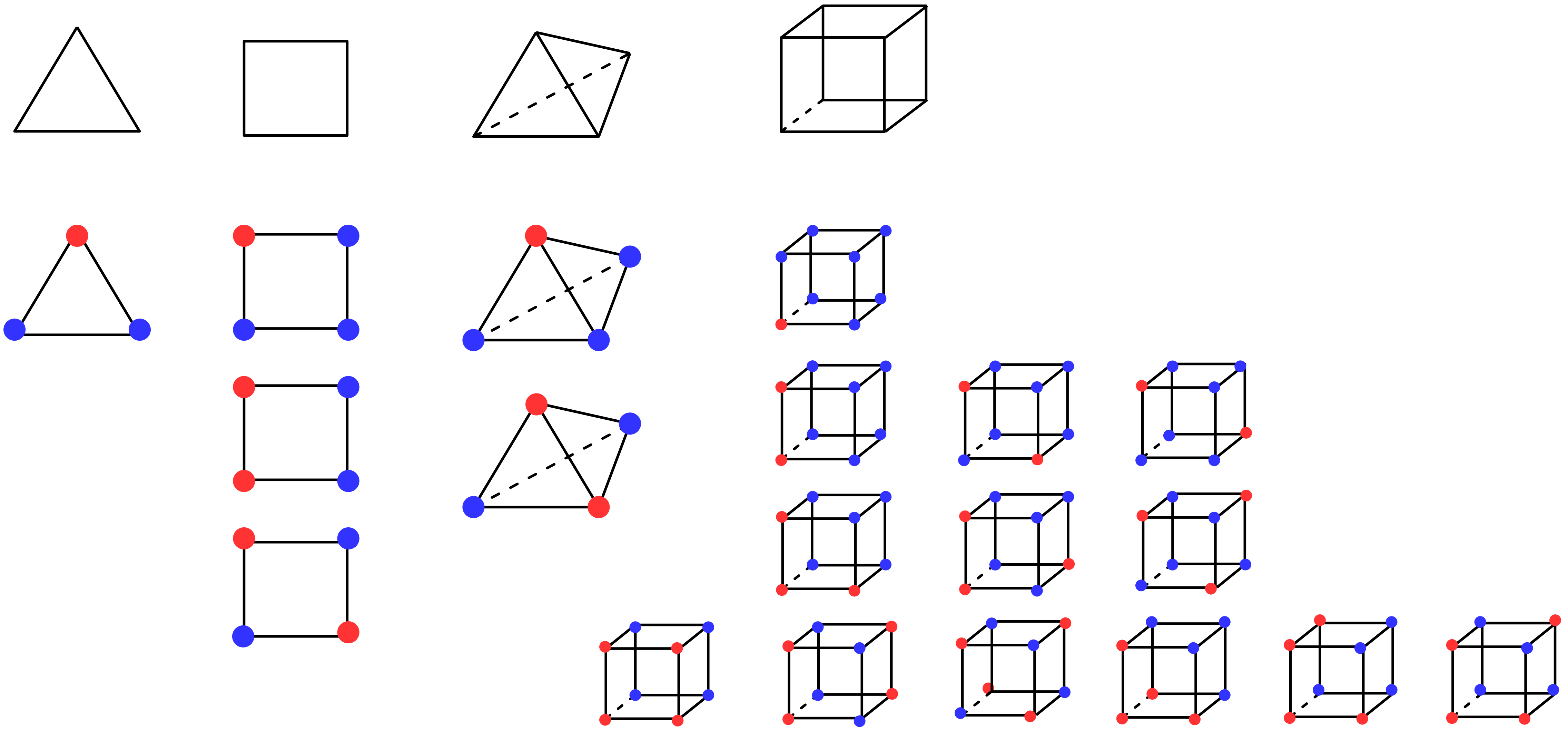
Midpoint on each edge which
passes from inside to outside.
Midpoints are connected



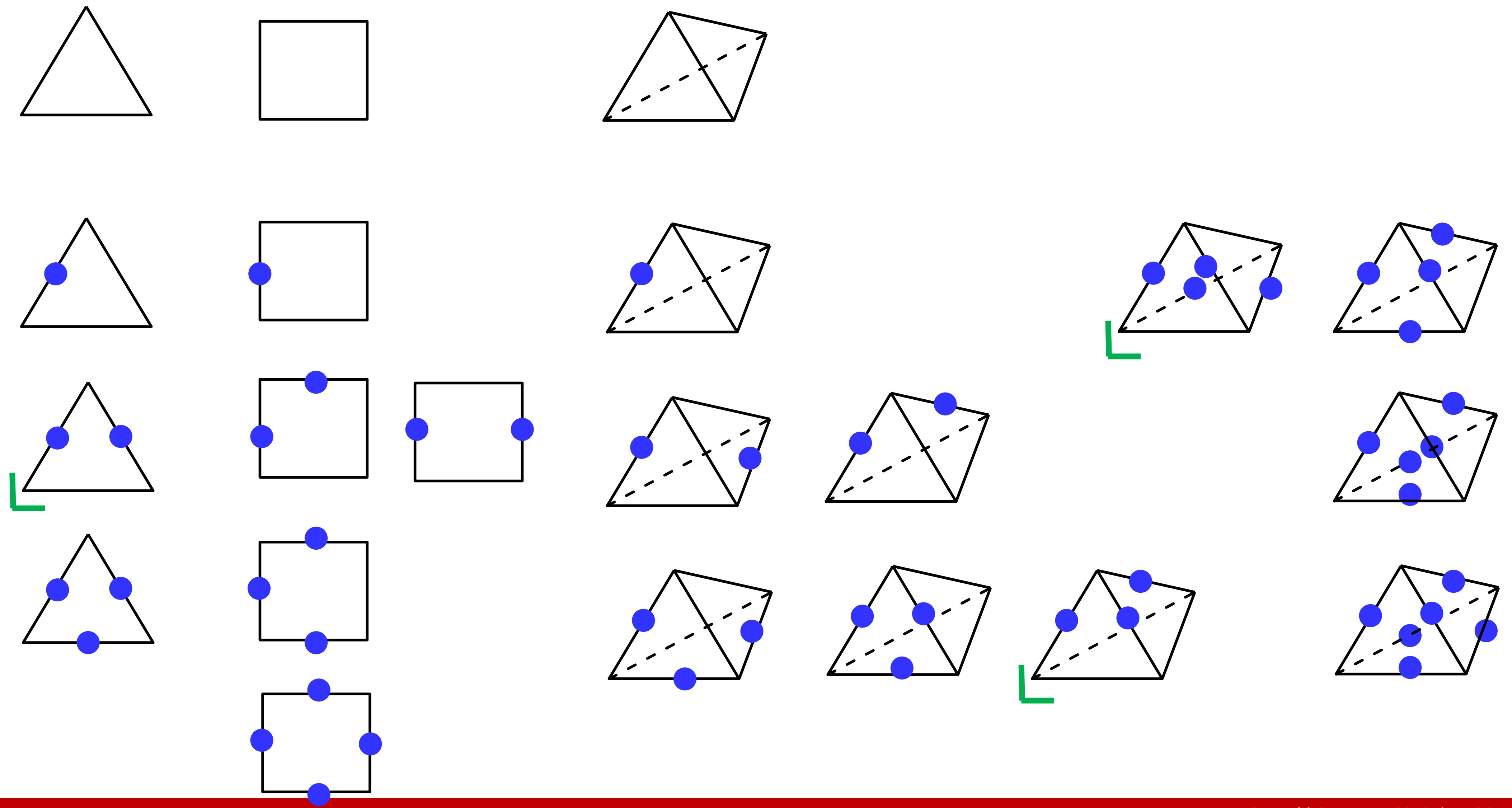
Midpoints are moved to their
geometry position

We extend the rules of Marching xx Methods to represent sharp edges and more than one part, we have to perform Boolean operations and the Marching xx grid is adapted to the geometric requirements.

Possible assignment of the nodes to 2 parts for Tria / Quad / Tetra / Cube

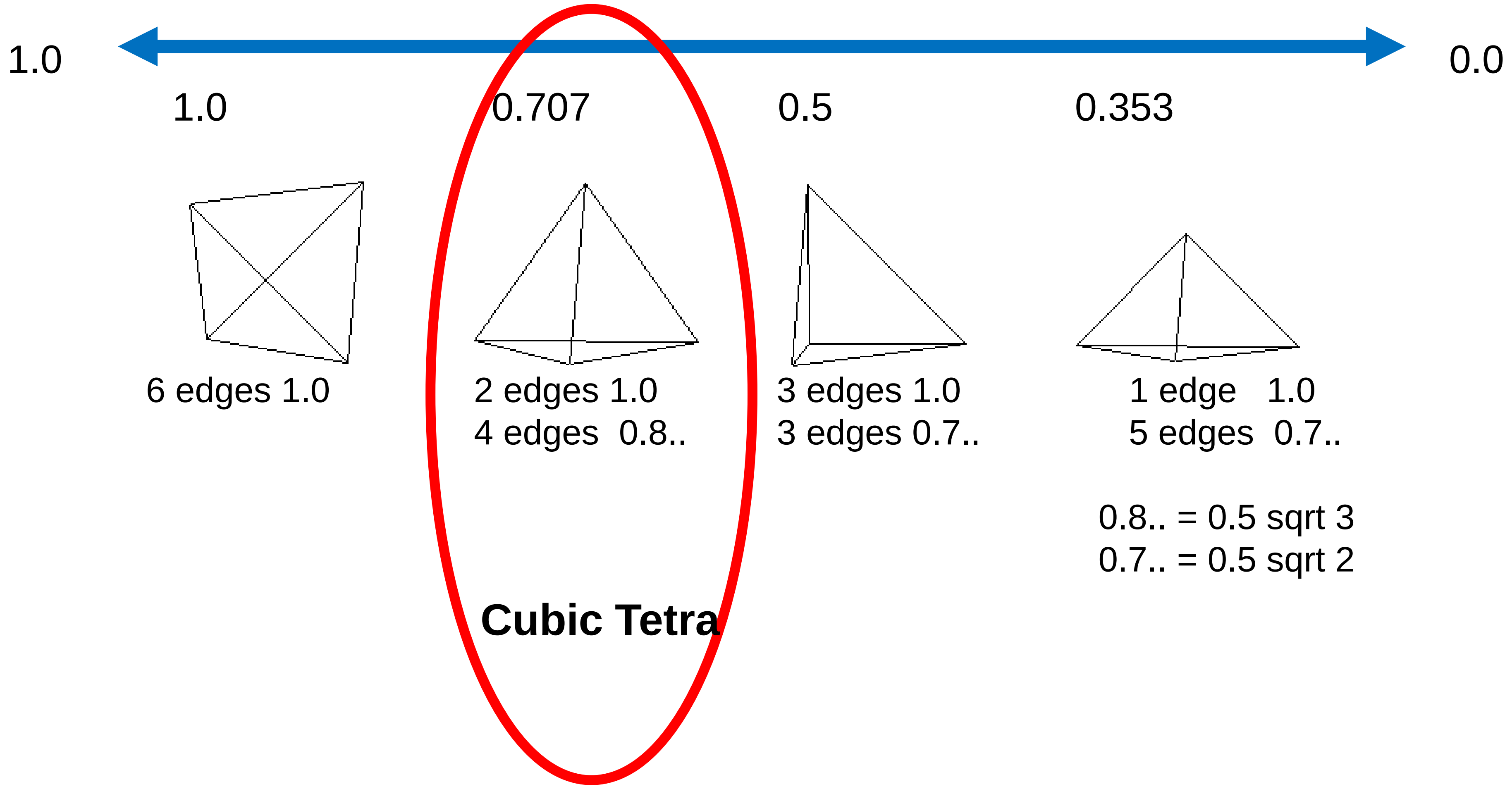


Possible edge splits for Tria / Quad / Tetra



Tetra Quality

Tetra quality is defined as Volume / max edge length **3 and is normalized to 1.0



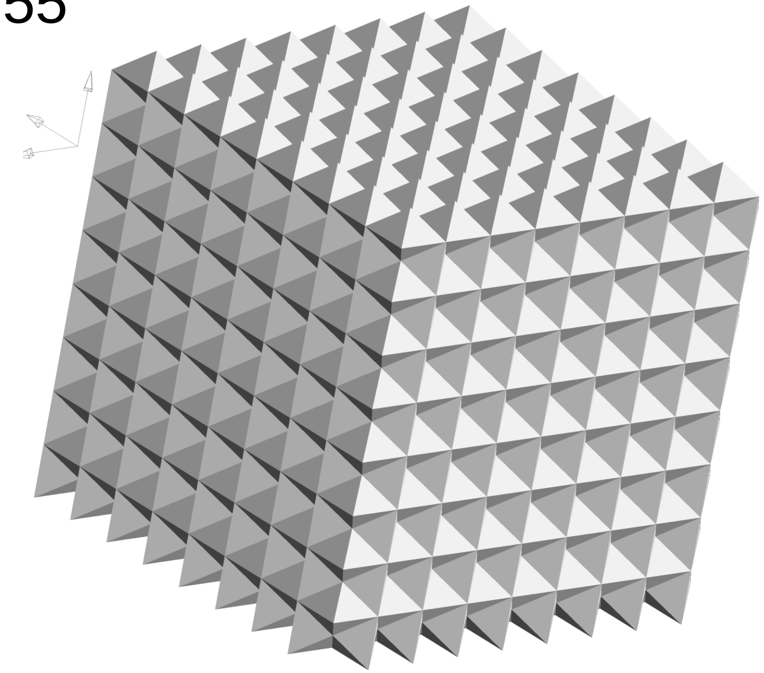
Tetra Quality

The Cubic Tetra is a tetra with cube properties

Space can be covered without gaps.
No new elements at full refinement.

Cubic Tetra quality	=	0.707
element quality after one non-full refinement	>	0.155
element quality after two non-full refinements	>	…

We start with a octahedron mesh.
Each octahedron is built with 4 Cubic Tetras.



Multigrid Marching Tetra Algorithm

0 Mark for refinement those edges and edges of triangles, tetras, which carry Marching Tetra Problems

1 Refine edges faces and volumes

2 Avoid bad elements by removing twofold non-full refinements

3 n times: goto 0

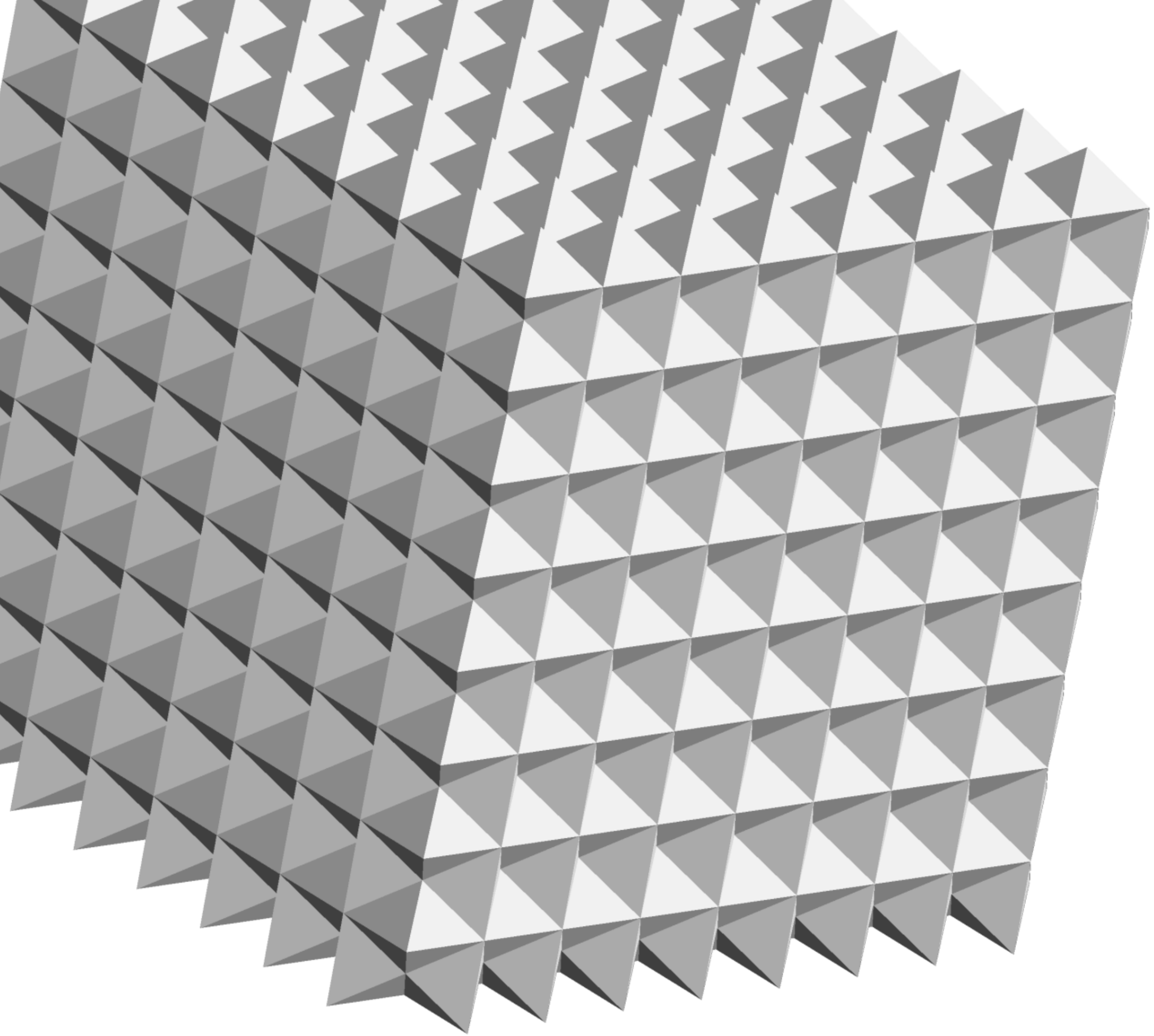
Perform Marching Tetra on this - good quality (> 0.155) - adaptive mesh:

Devide triangles at the center to display feature lines + T-joints.
Devide tetras at the center to display corners.
Decrease element quality to improve geometrical truth (i.e. move nodes to their geometry position).
Increase element quality by mesh coarsening.

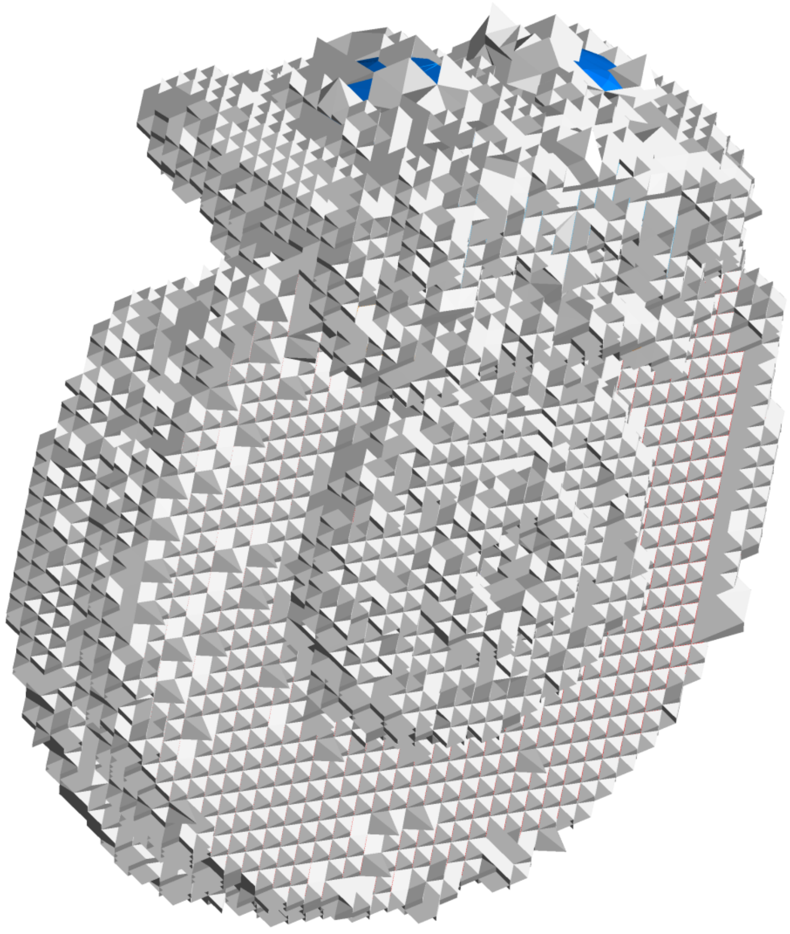
Disc Brake Pictures

18	parts in a box of x = 400 mm y = 155 mm z = 360 mm
80	mm initial edge size, 8x8x8 octahedron initial mesh
165	mm disc diameter

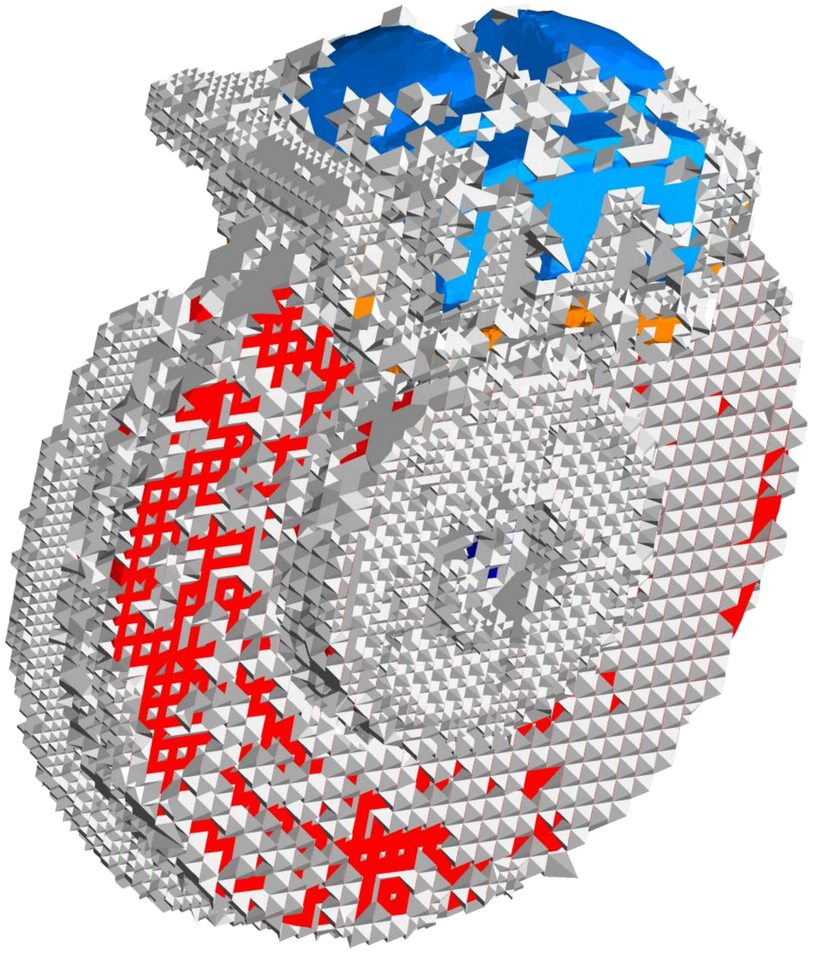
levels of refinement	2	3	4	5	6	7
1000 surface nodes	24	61	134	269	508	927
1000 surface triangles		134				1966
1000 tetra nodes		73				1285
1000 tetras		396				7176
imprints		39				26



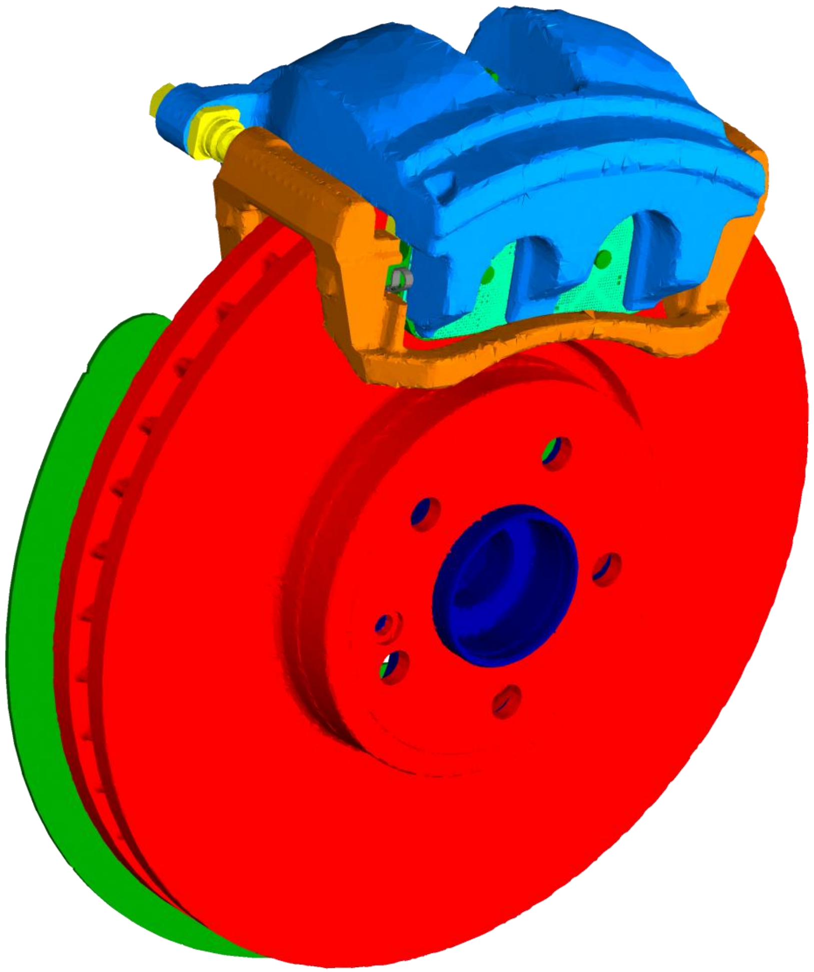
initial mesh



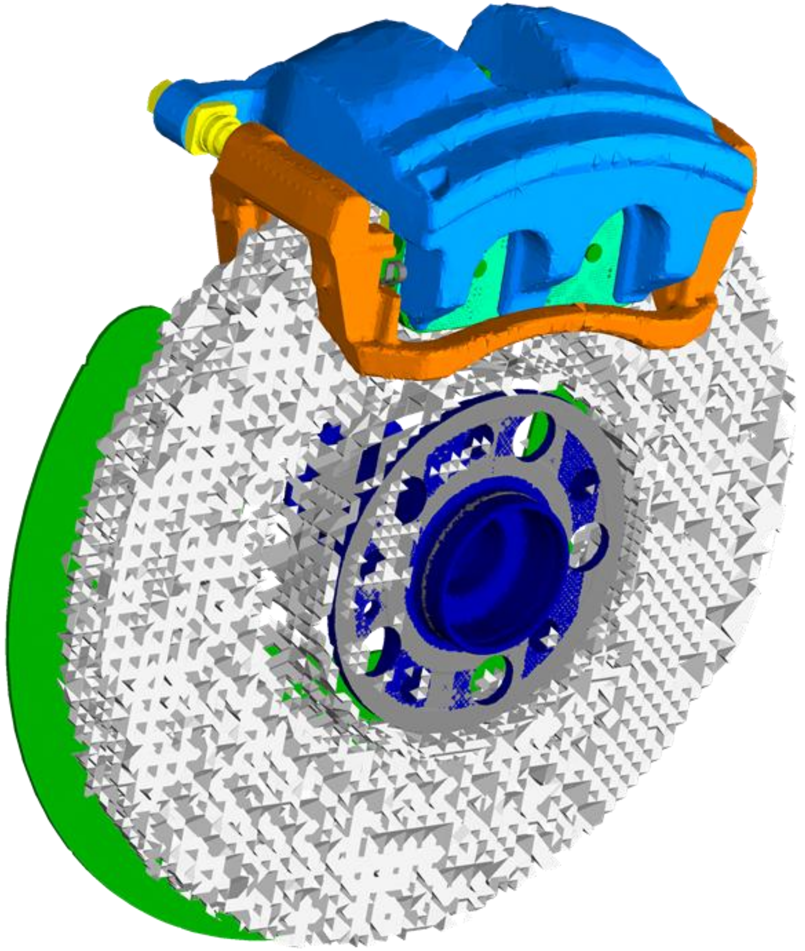
tetras of level 3+higher



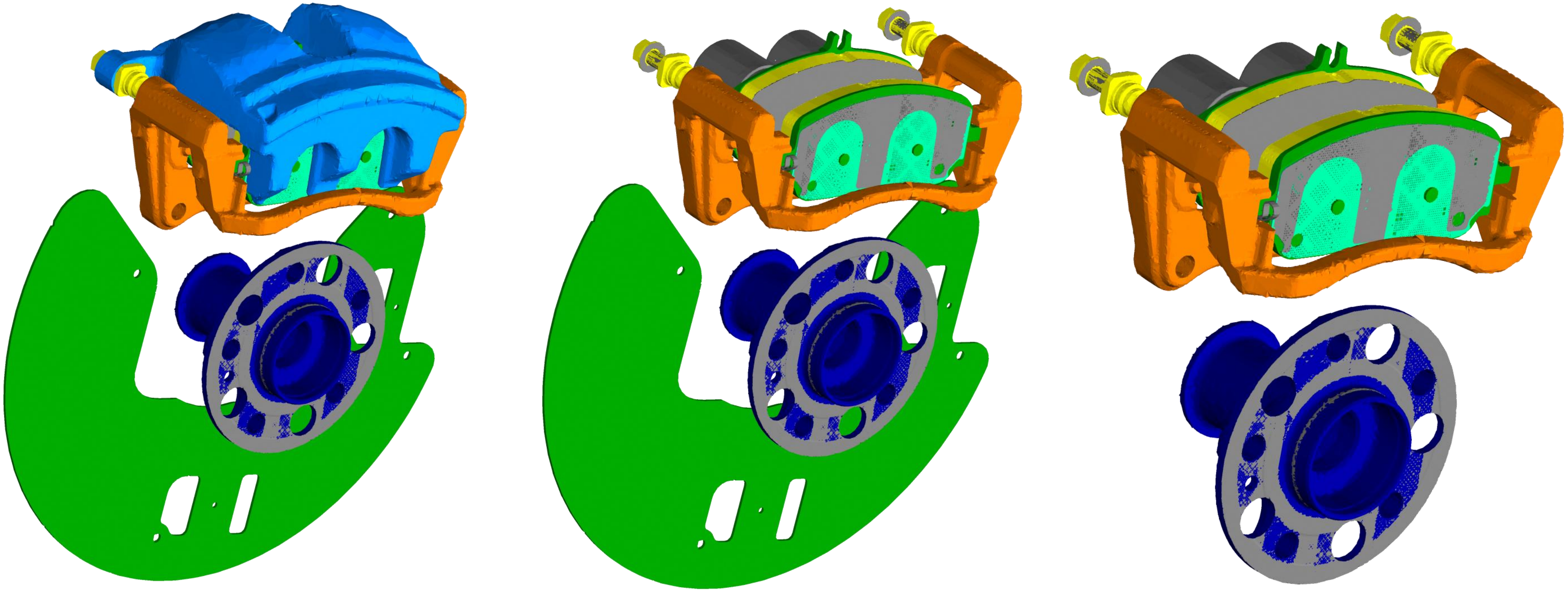
level 4+higher



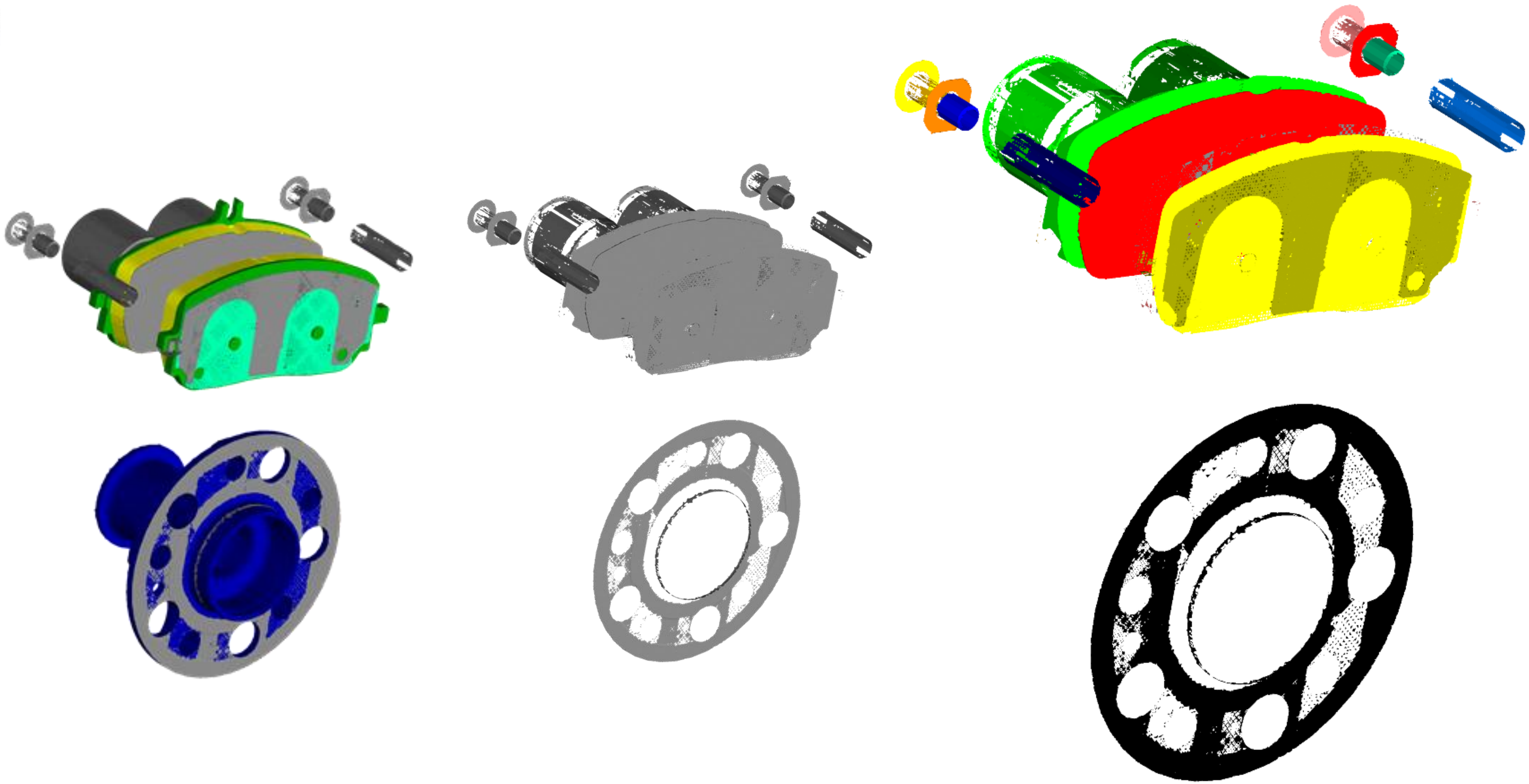
MC surface mesh



disc surface + high level disc tetras removed

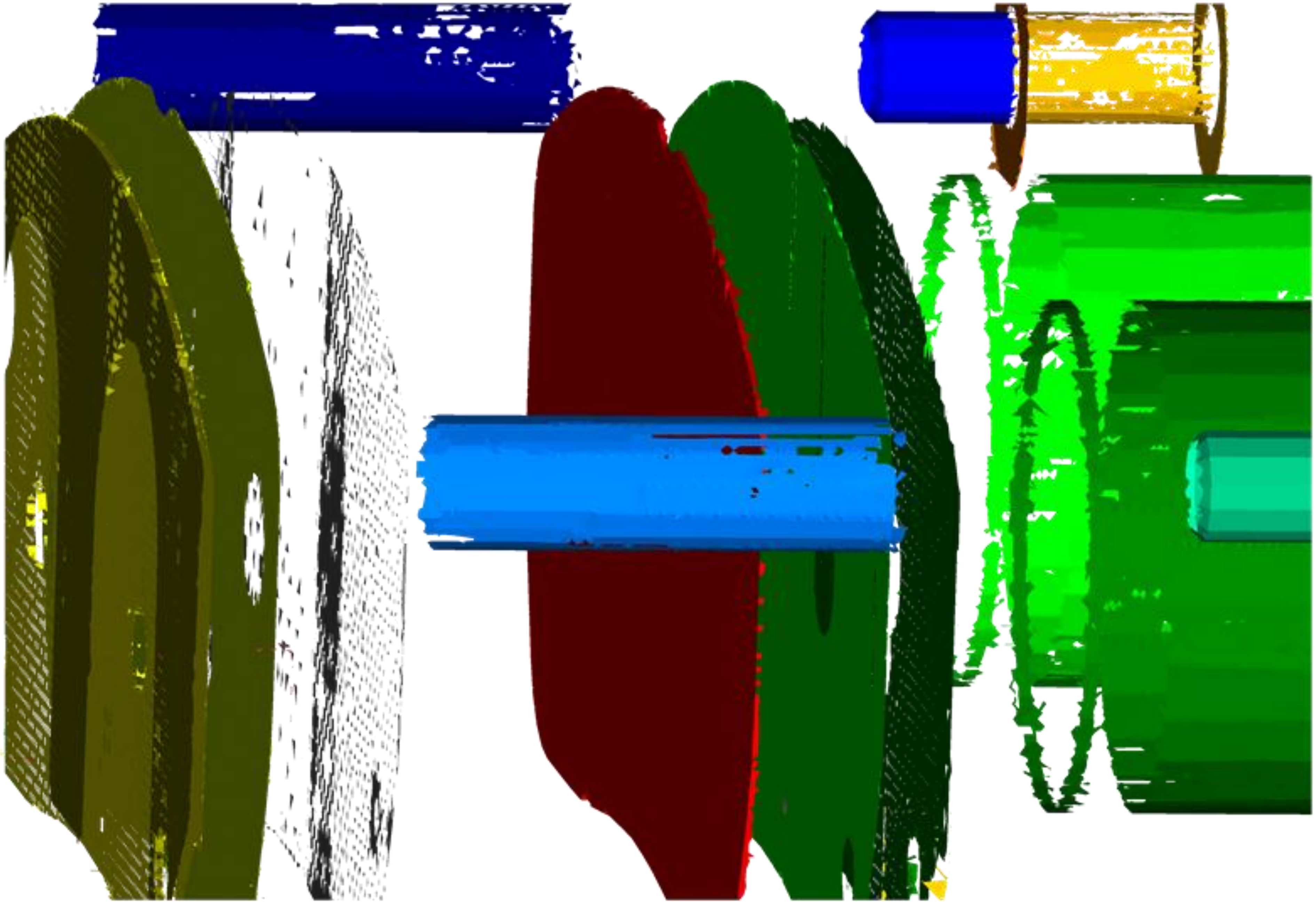


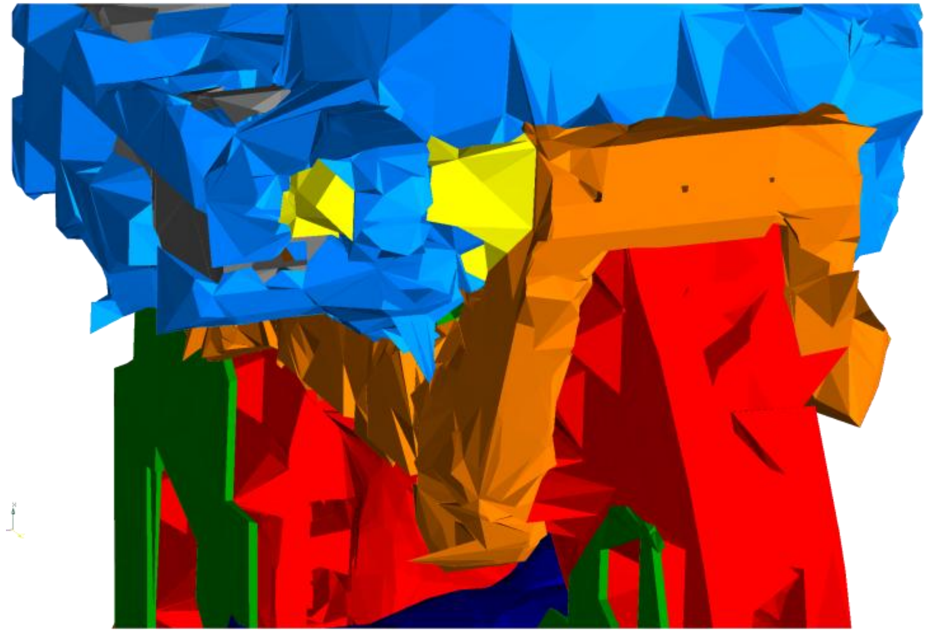
parts are successively removed, imprint area (grey) remains

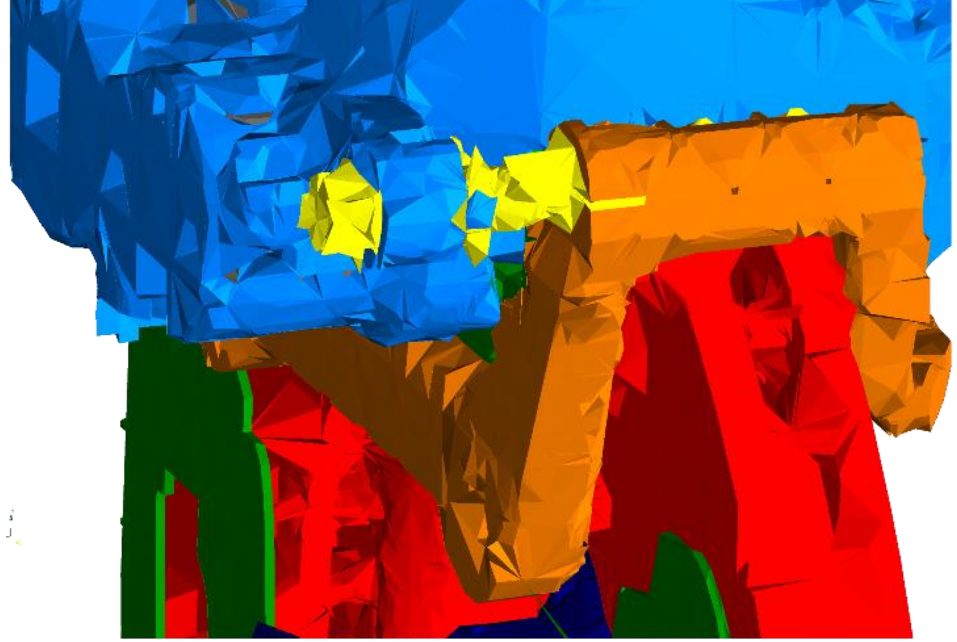


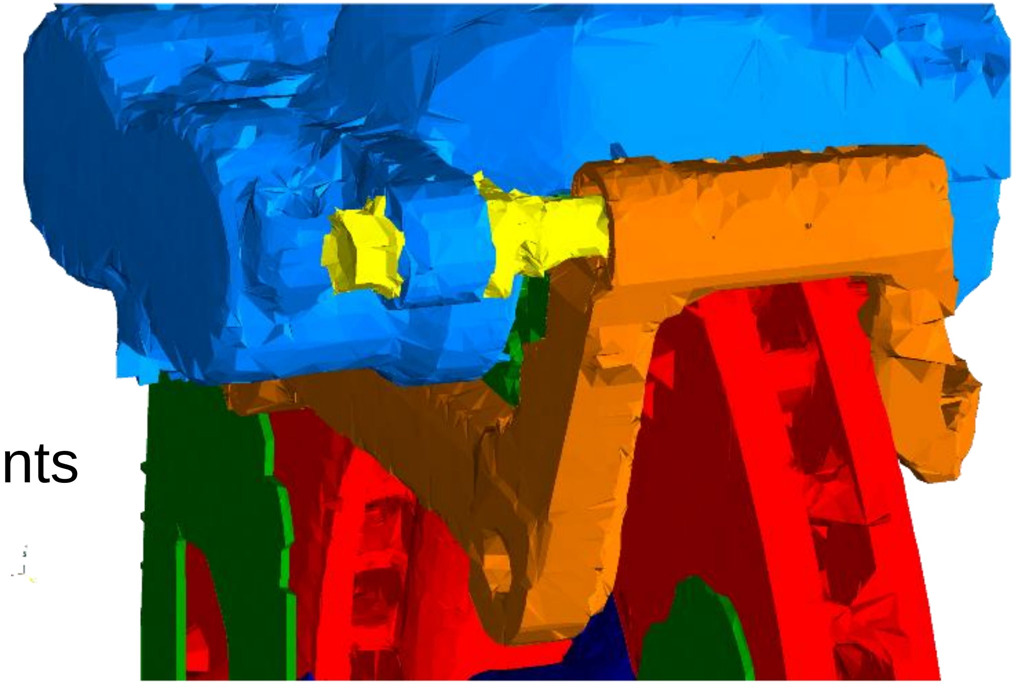
pure imprint triangles

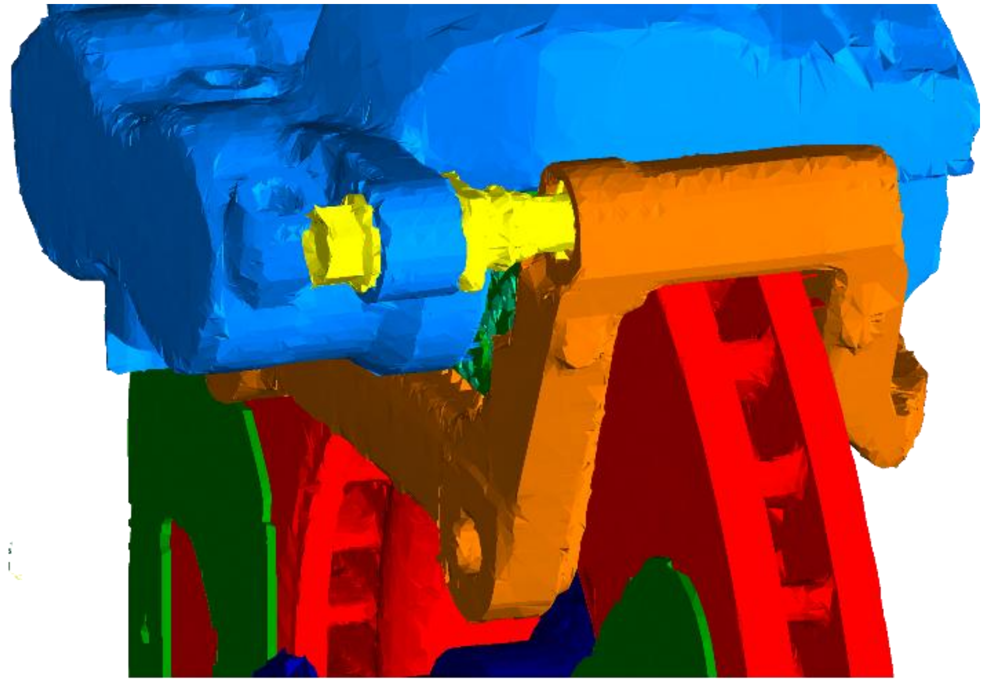
... coloured to indicate
pair of parts of the imprint











2,3,4 and 5
multigrid refinements

Thank you

to Daimler AG for supporting this work

and to my audience