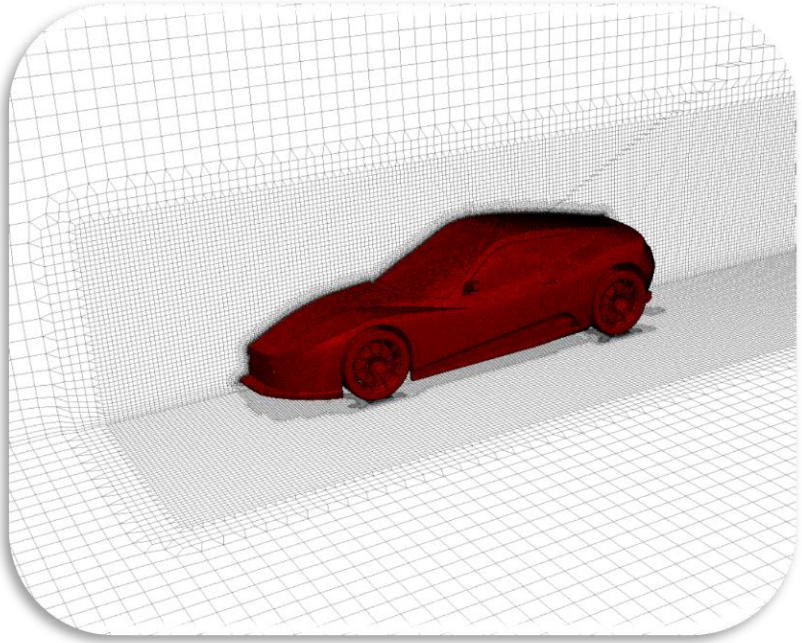
A Dualised Hex-Mesh Generator With Cell Quality Optimisation



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- Introduction
  - Overview of snappyHexMesh
  - Issues with snappyHexMesh
- Methodology of new mesh generator
- Example Cases
- Conclusions

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snappyHexMesh | Overview

- Introduced 3rd OpenFOAM Workshop in Milan 2008
  - "Automatic Parallel Polyhedral Mesh Generation on Complex Geometries in OpenFOAM" E. de Villiers, A. Jackson (Engys), M. Janssens (OpenCFD Ltd)
- A version of snappyHexMesh called helyxHexMesh continues to be developed by Engys

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snappyHexMesh | Overview

- Automatic hex dominant mesh generation
- Surface, feature and proximity refinement
- Inside/outside/distance based volumetric refinement
- Surface snapping and feature capturing
- Automatic cell-zone and face-zone creation
- Surface layer insertion
- Parallel

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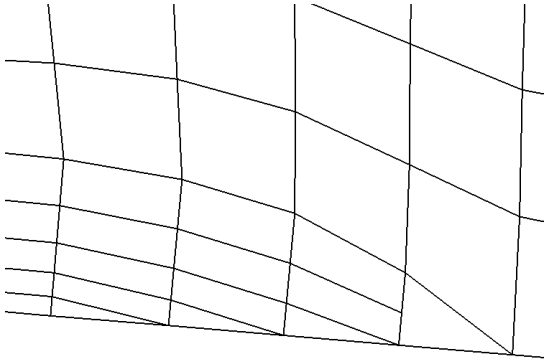
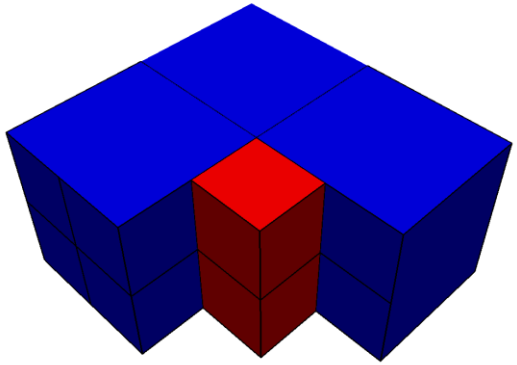
snappyHexMesh | Issues

- Local layer collapses where mesh quality cannot be satisfied make low y+ meshes difficult to achieve



- Cell volume changes of 8:1 at refinement interfaces can impact on accuracy of CFD simulations



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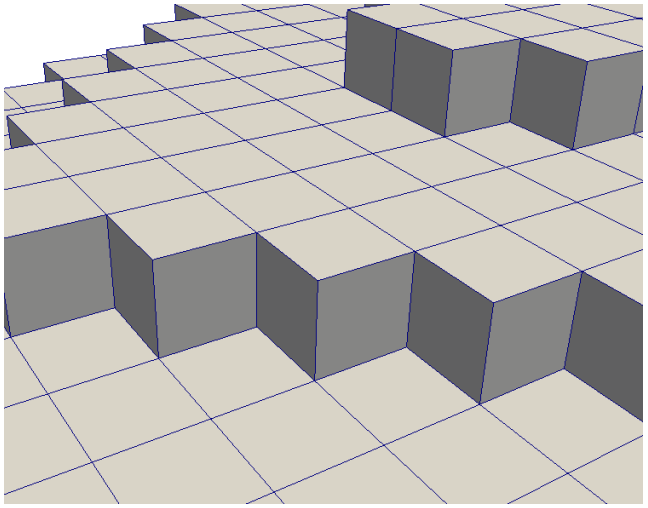
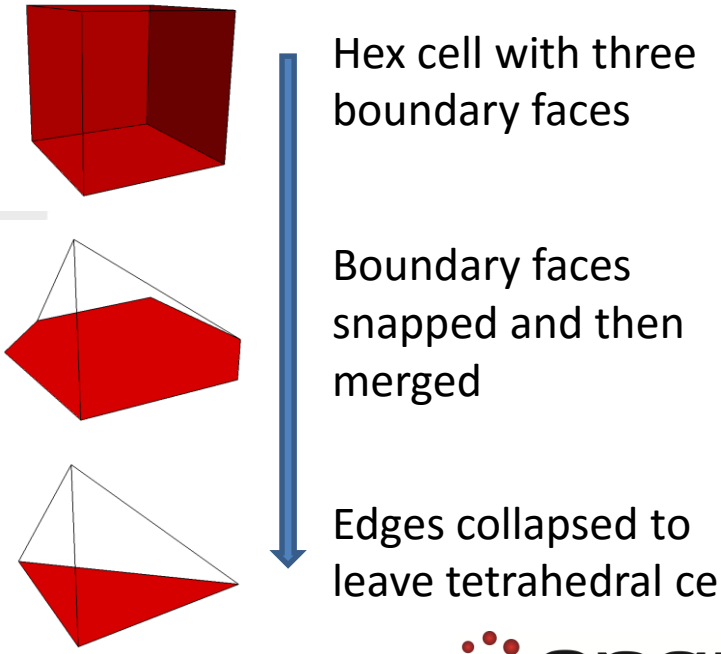
snappyHexMesh | Issues

- snappyHexMesh modifies cell topology at the surface by merging faces and collapsing edges





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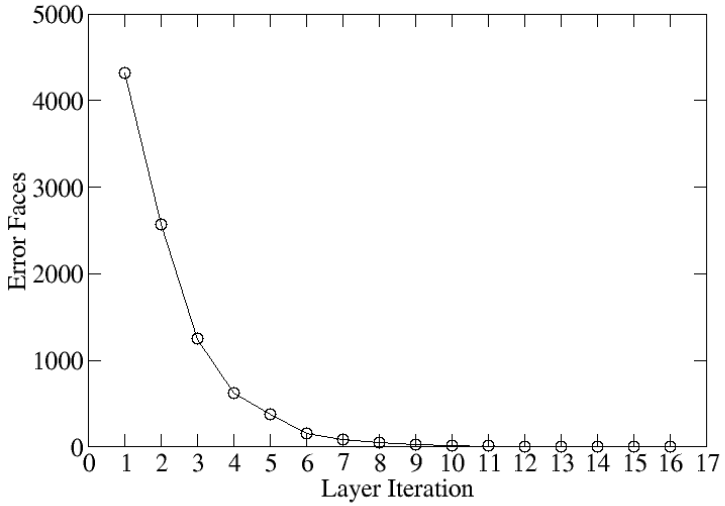
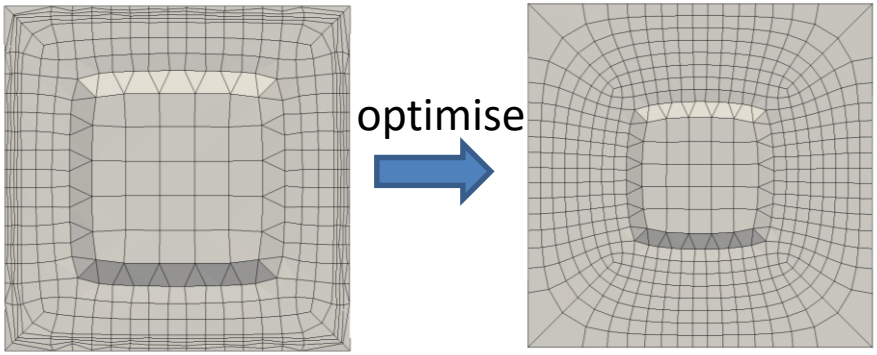
snappyHexMesh | Issues

- snappyHexMesh performs a number of layer insertion iterations to remove errors in the mesh which can slow down meshing run times



- snappyHexMesh has a reversal mechanism to satisfy final mesh quality but has no active mesh improvement methods



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Methodology | Overview

- Requirement to generate high quality CFD meshes on complex geometries automatically
- To improve upon snappyHexMesh's known issues a dualised mesh approach is proposed
  - Layer generation on all surfaces without the need to collapse layers
  - Non-iterative layer insertion
  - Eliminate face merging step
  - Reduce 8:1 volume change at interface boundaries
  - Optimisation step to improve mesh quality

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Methodology | Stage 1 | Refinement

- Mesh refinement
  - Feature refinement
  - Surface refinement
  - Proximity refinement
  - Volumetric refinement
  - Inside/outside check
  - Optional small leak or larger scale wrapping stage

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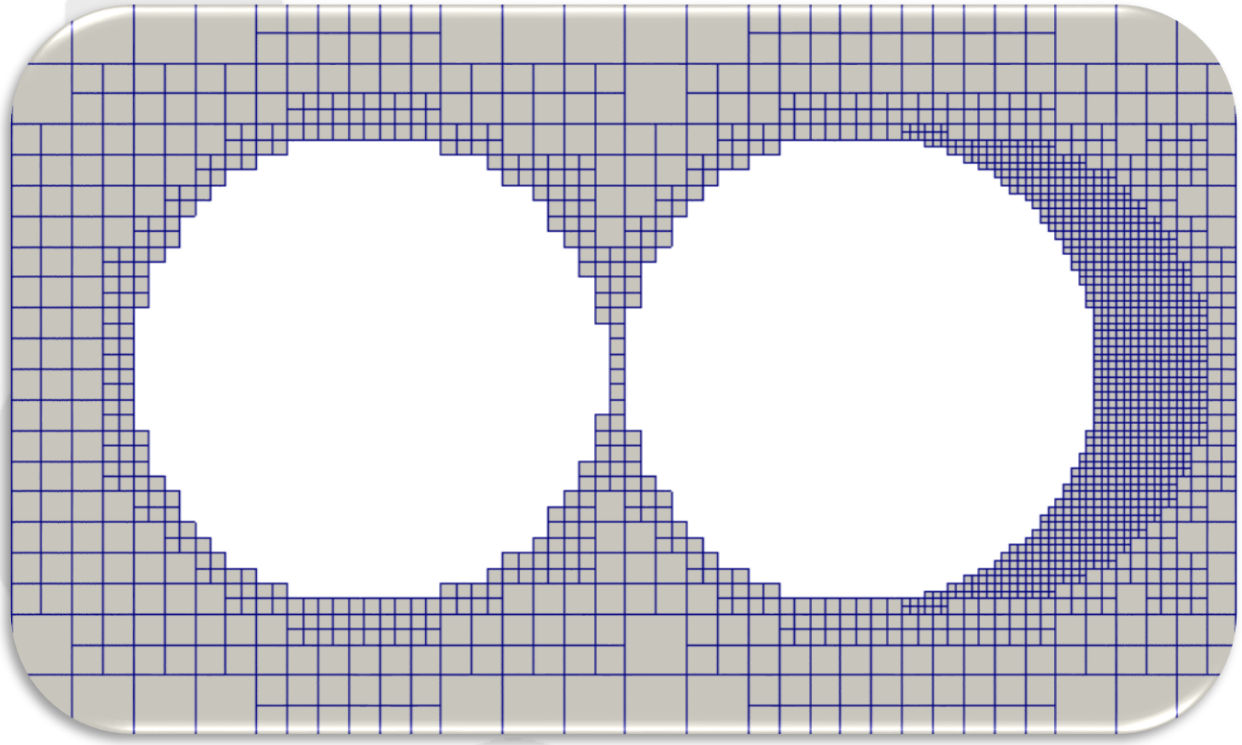
Methodology | Stage 1 | Refinement

- Refinement engine used to generate a base castellated starting mesh



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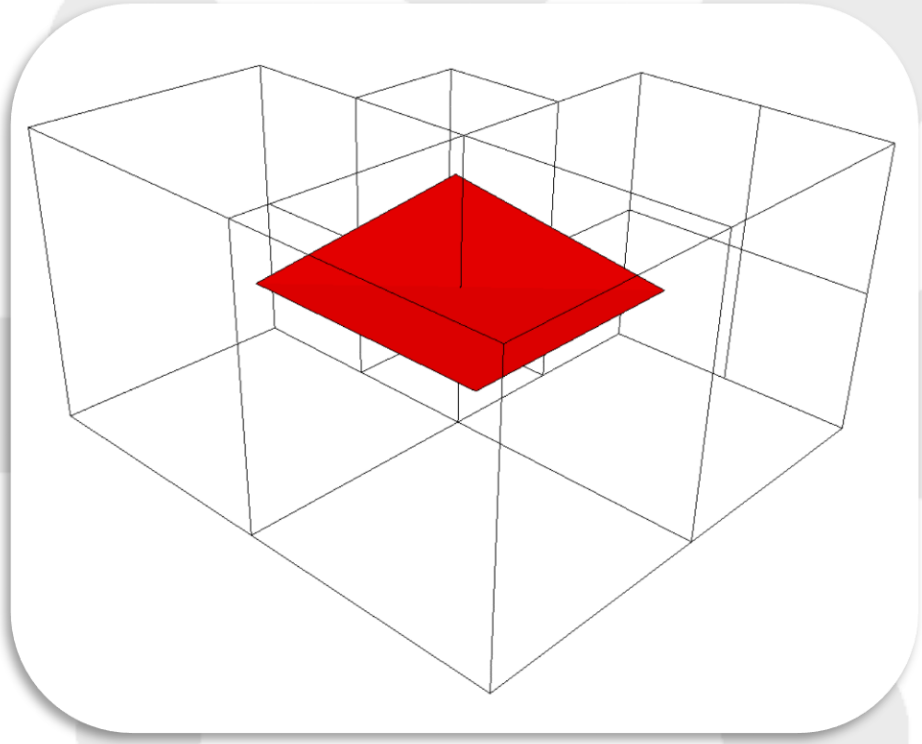
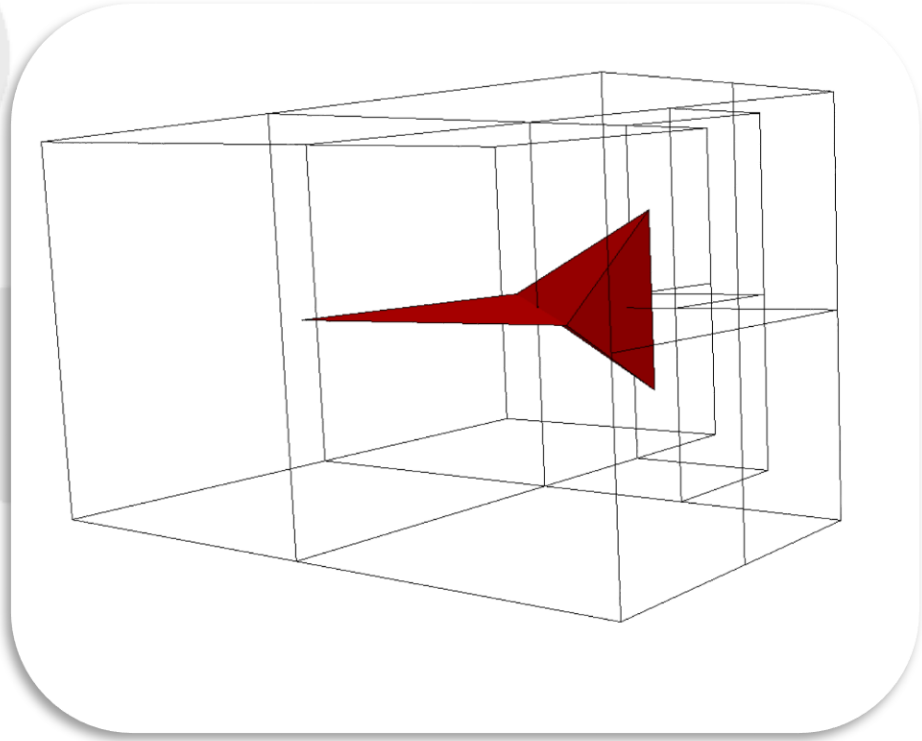
Methodology | Stage 2 | Internal Layers

- Dualised mesh at refinement interfaces can generate degenerate cells





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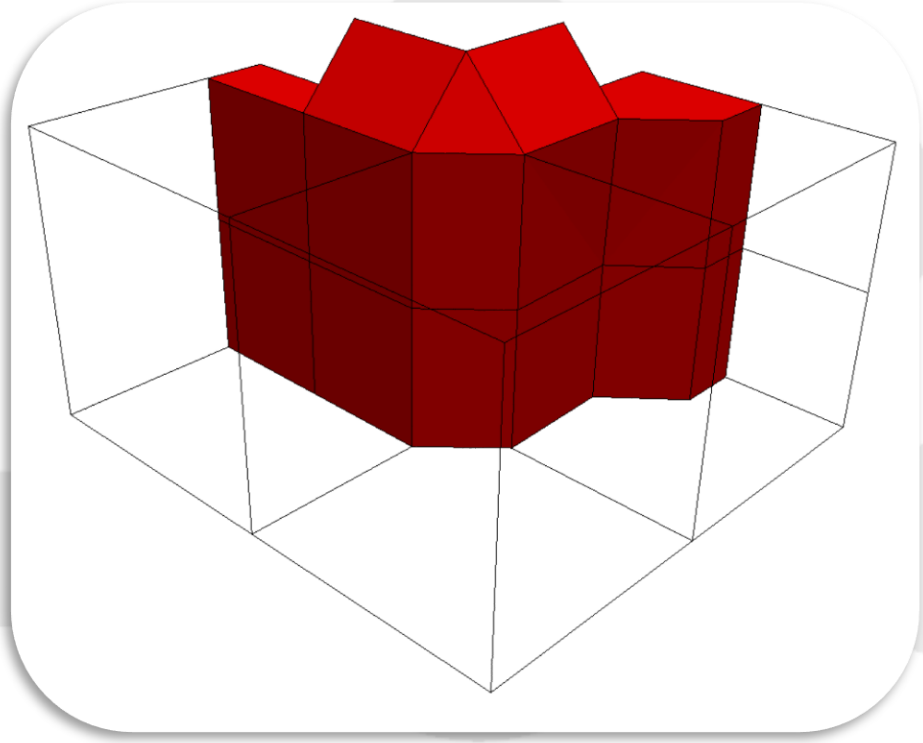
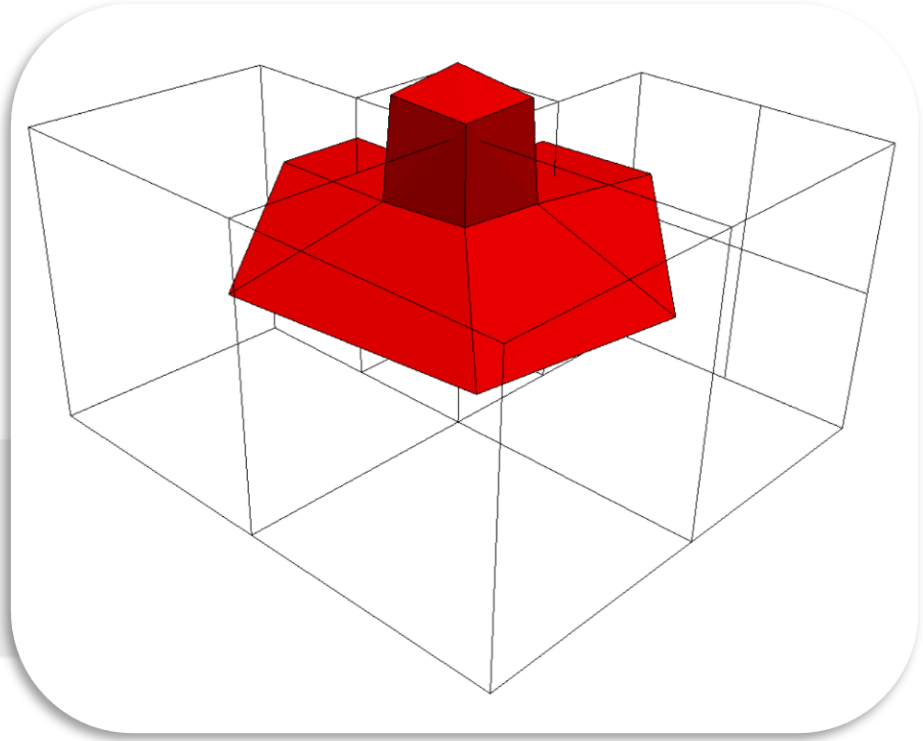
Methodology | Stage 2 | Internal Layers



Single layer of cells added at all refinement interface



Manifold dual cell

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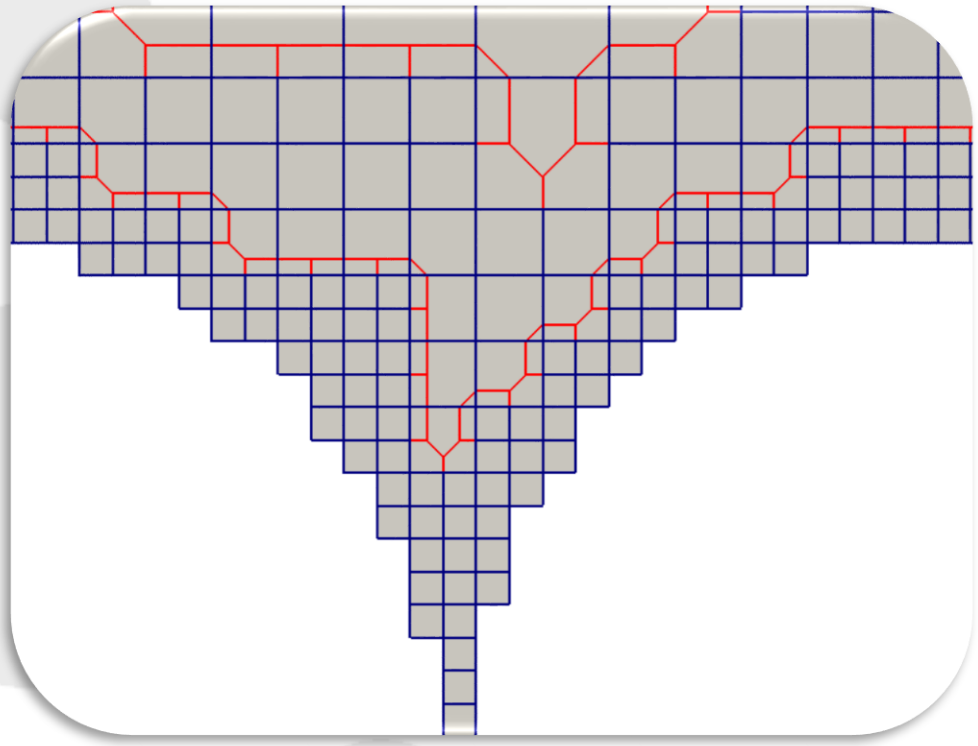
Methodology | Stage 2 | Internal Layers

- A Layer of cells are added at all refinement interfaces



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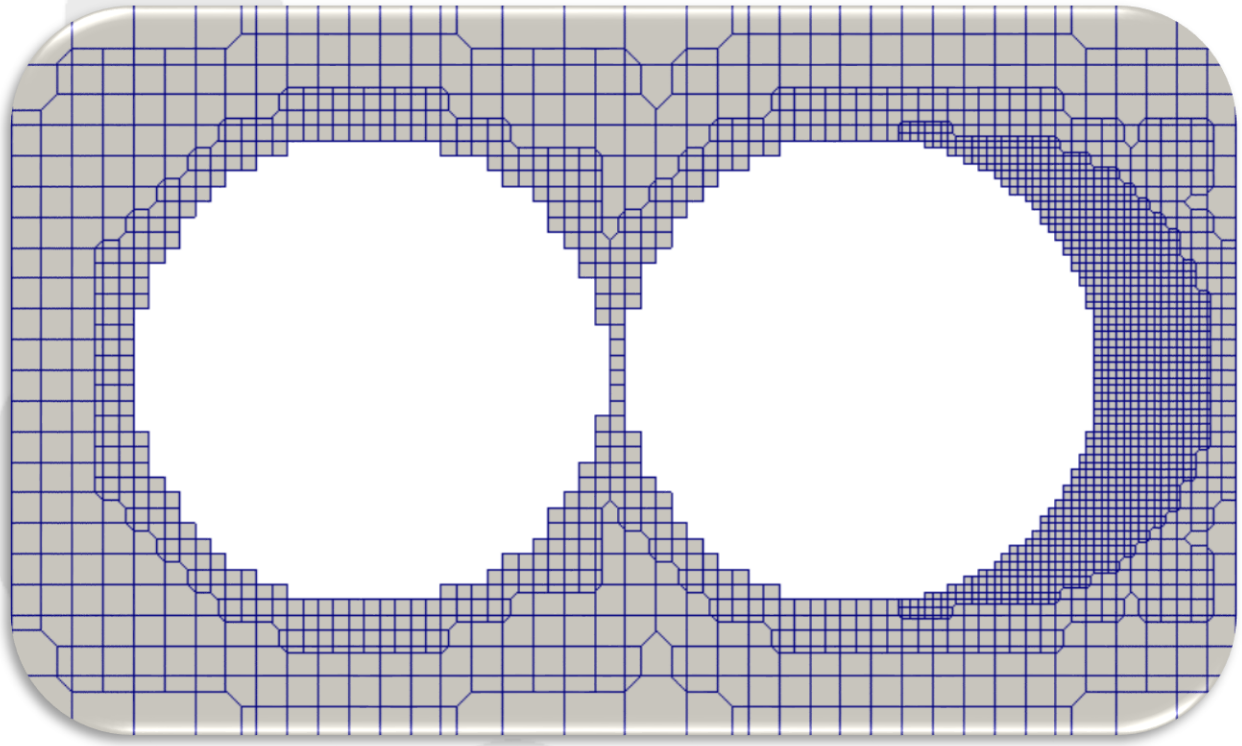
Methodology | Stage 2 | Internal Layers



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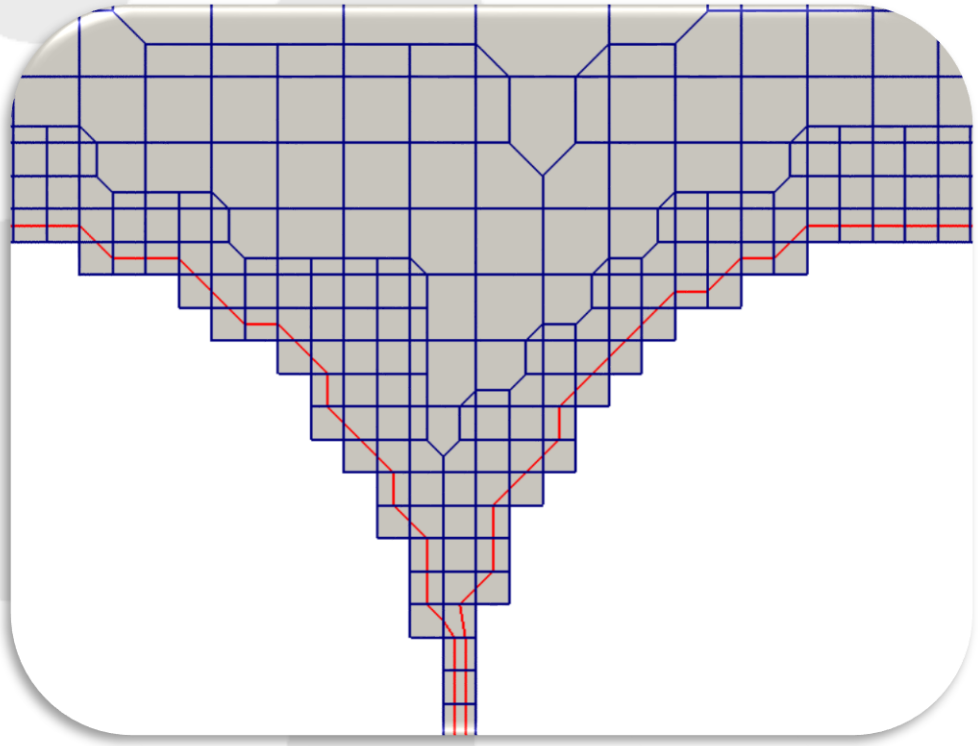
Methodology | Stage 3 | Split Boundary Cells

- To generate a single layer of cells at the boundary any cell connected to the boundary is split using boundary connected edges.



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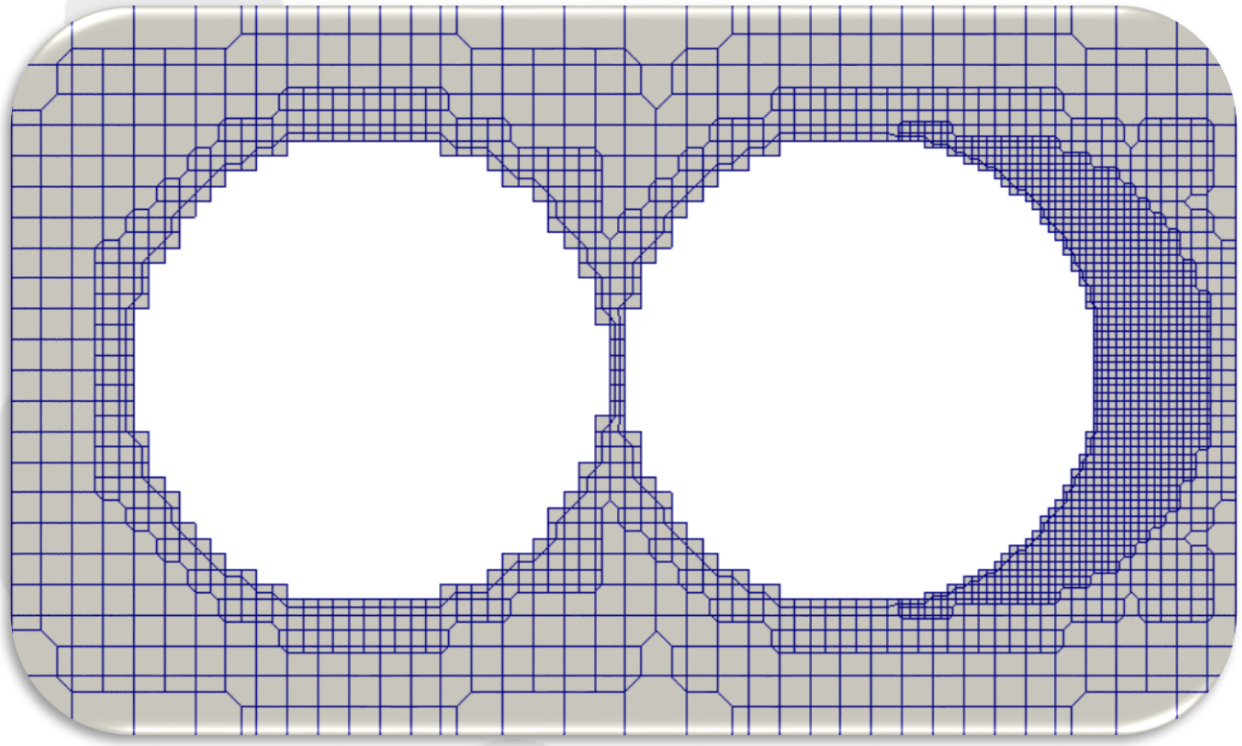
Methodology | Stage 3 | Split Boundary Cells



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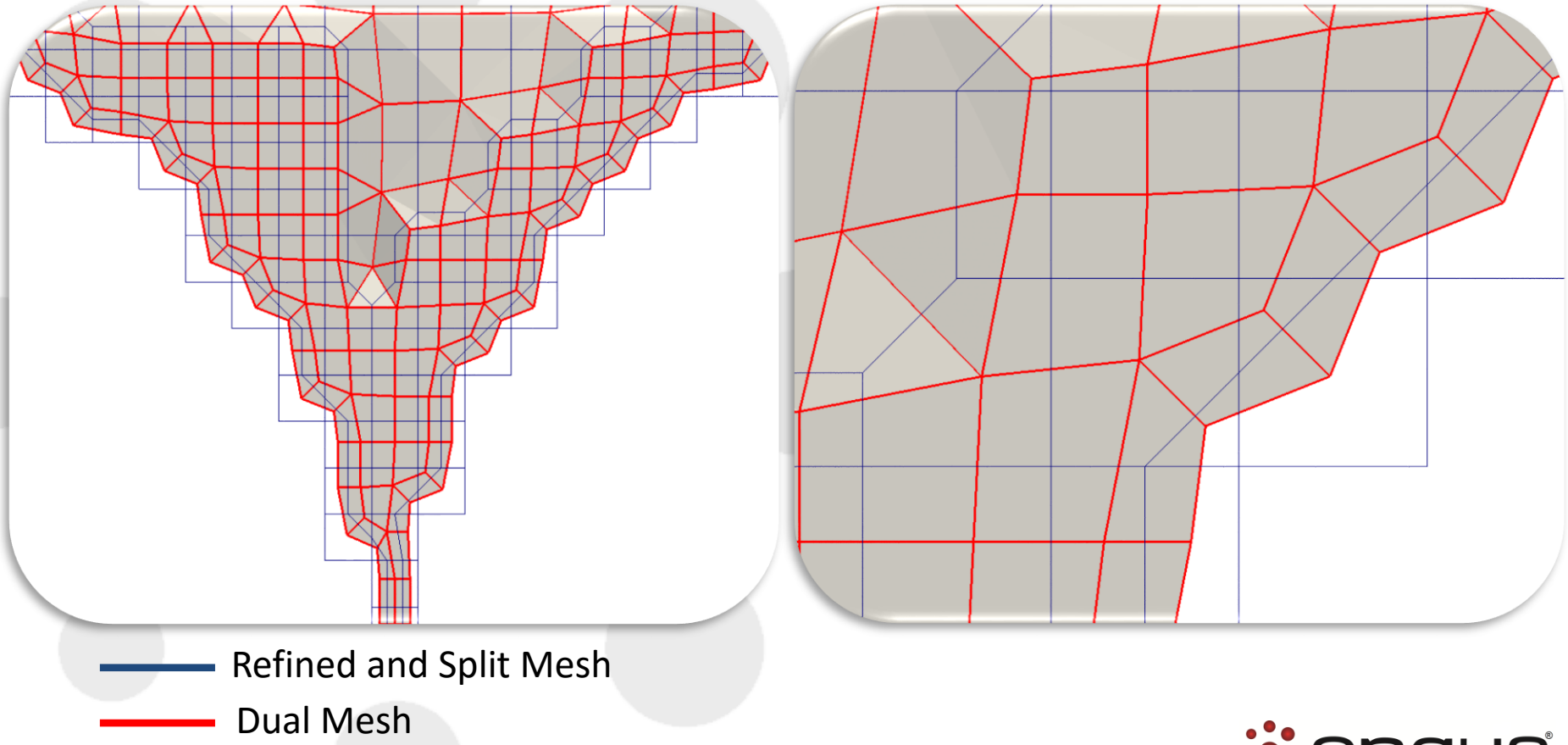
Methodology | Stage 4 | Dual Mesh

- Dual mesh created with a single layer of cells at boundary with one boundary face per cell (no merging of boundary faces required)



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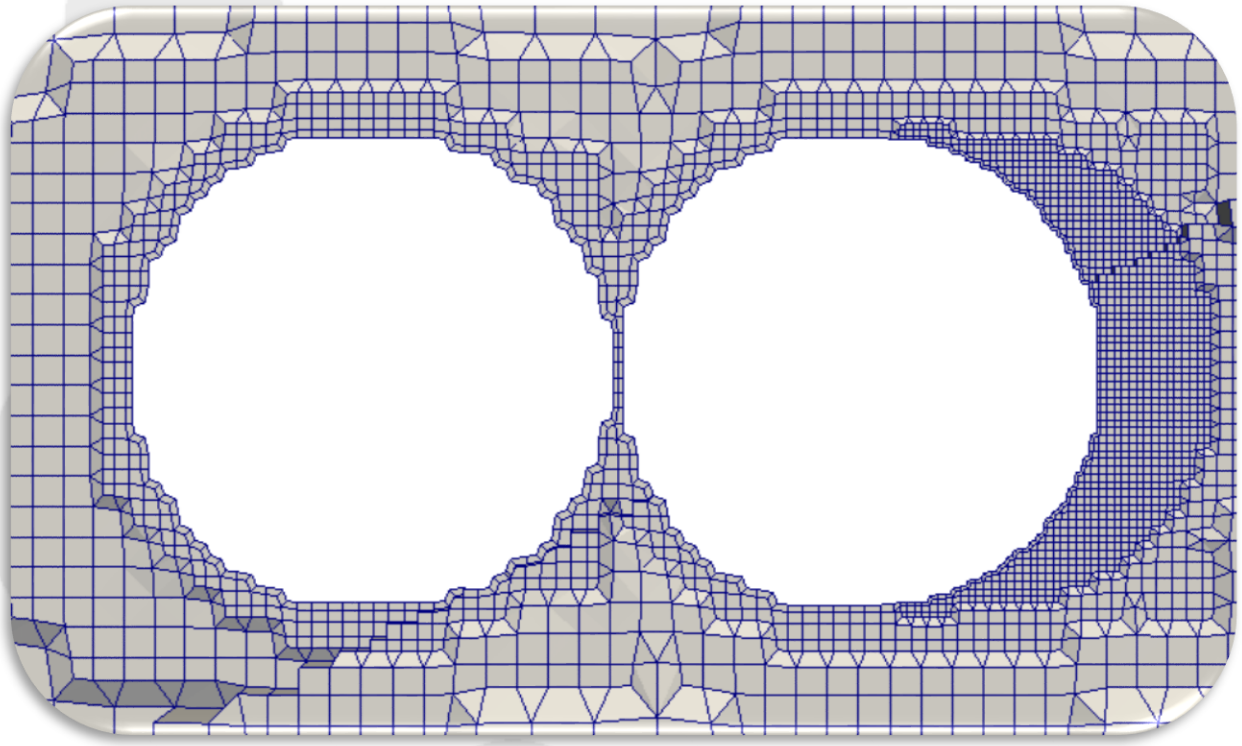
Methodology | Stage 4 | Dual Mesh



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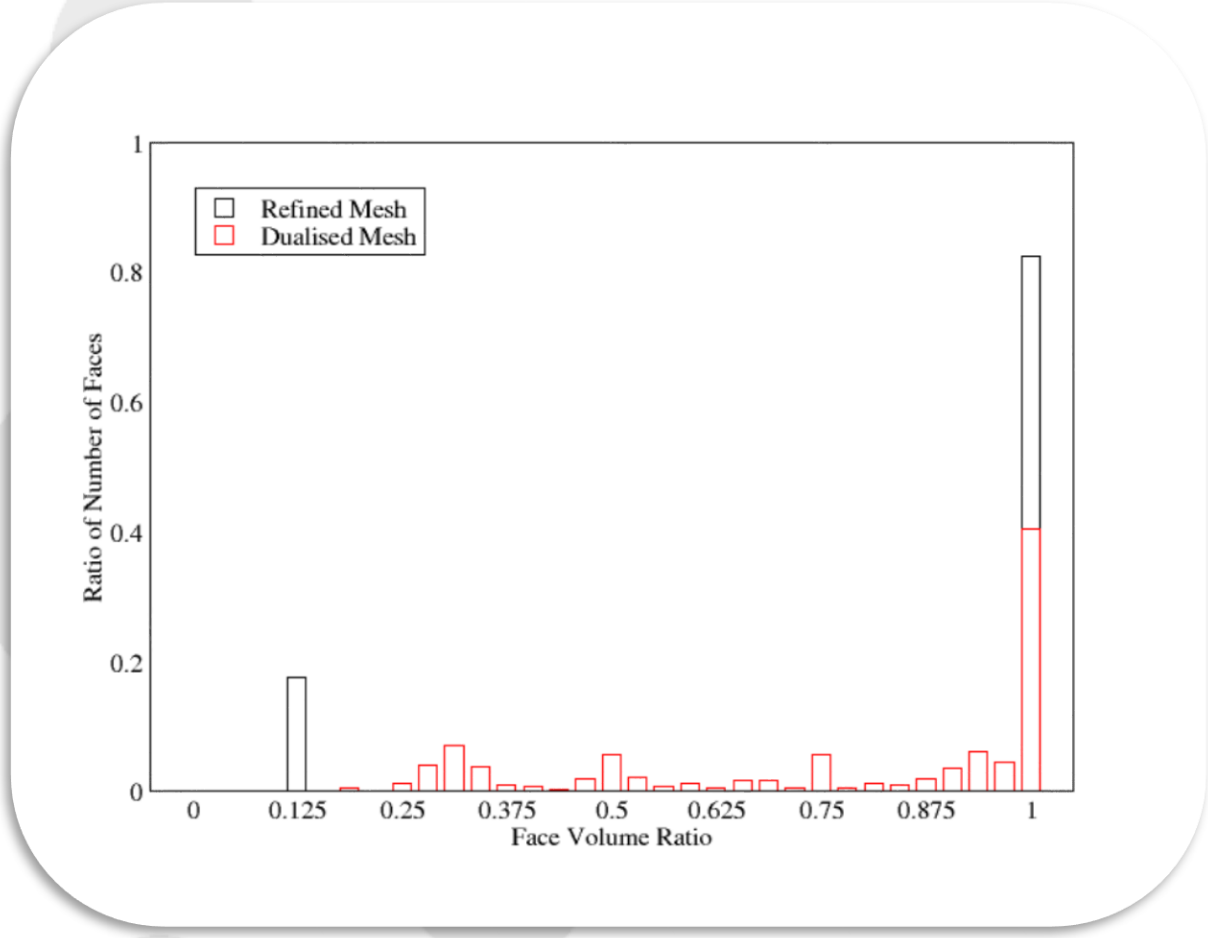
Methodology | Stage 2 | Dual Mesh

- The mesh dualisation smooths the mesh increasing the minimum face volume ratio from 1:8



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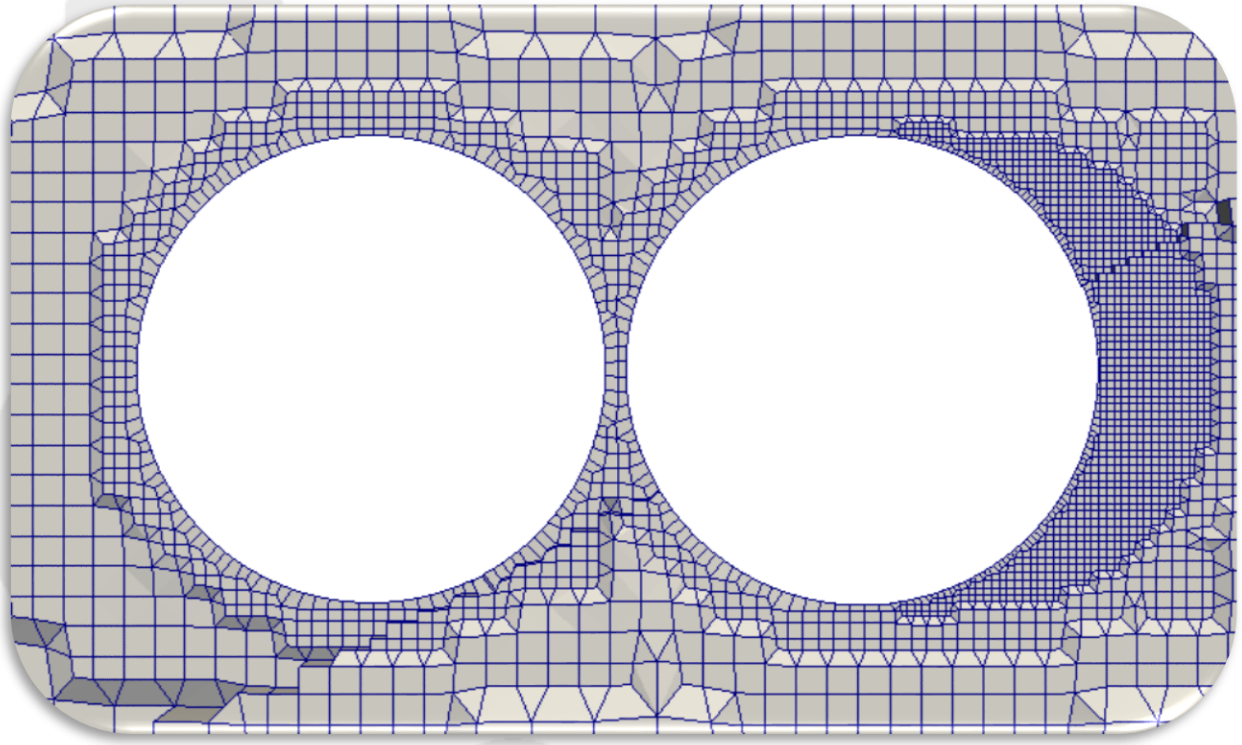
Methodology | Stage 5 | Snap To Surface

- Iteratively snap to the surface to allow capture of any feature edges that may be present



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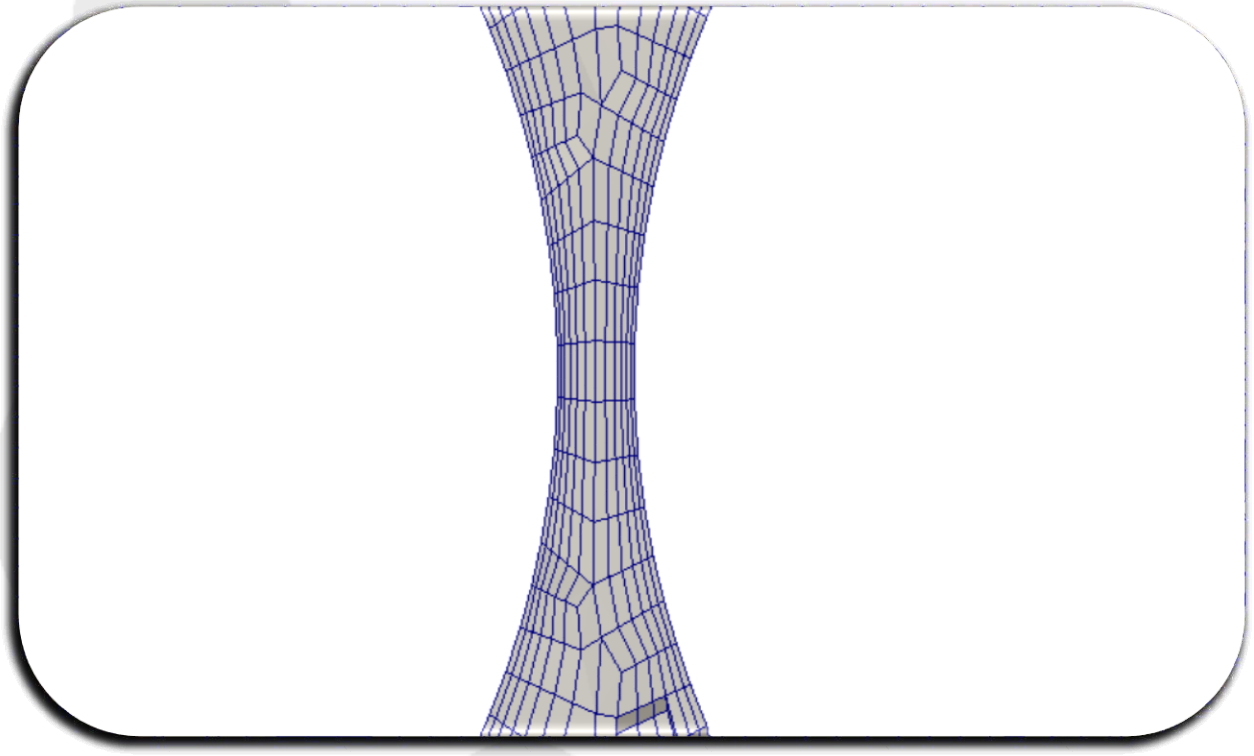
Methodology | Stage 6 | Layers

- Additional layer cells can be added by splitting first layer cell. This is coupled with a mesh optimisation stage



Layers added to gap region

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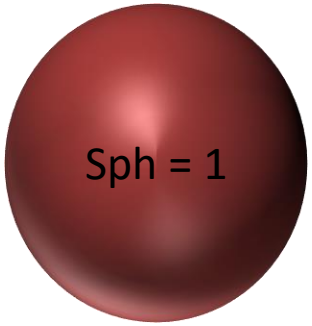
Methodology | Stage 7 | Optimisation

- New method for optimising CFD meshes
- Based on Sphericity

$$Sphericity = \frac{\left(\frac{6}{\pi}V_c\right)^{1/3}}{\left(\frac{1}{\pi}S_c\right)^{1/2}}$$



- Maximizing Sphericity leads to better mesh quality
- Heuristics techniques to handle curved surfaces, feature edges/points and high aspect ratio layer cells

Methodology | Stage 7 | Optimisation

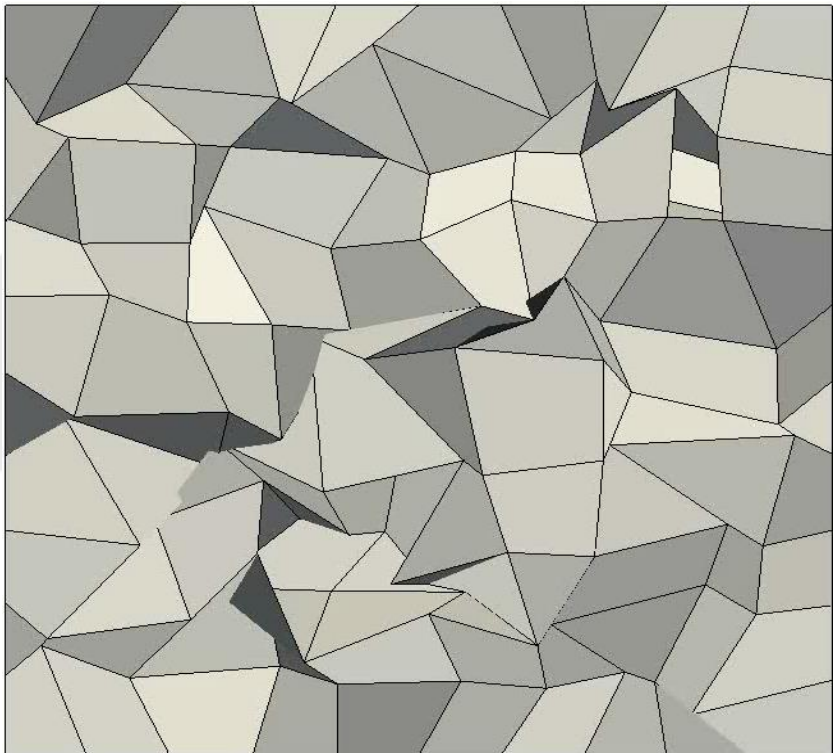
- Analytical differentiation of Sphericity

$$\vec{x}_{new} = \vec{x}_{old} + eta \cdot \overrightarrow{G_p} \text{ where } \overrightarrow{G_p} = \frac{1}{Z} \cdot \sum_{n=1}^{Z} \frac{\partial Sph}{\partial \vec{x}_{old}}$$

- $\overrightarrow{G_p}$: total Sphericity derivative of point P from all contributing cells

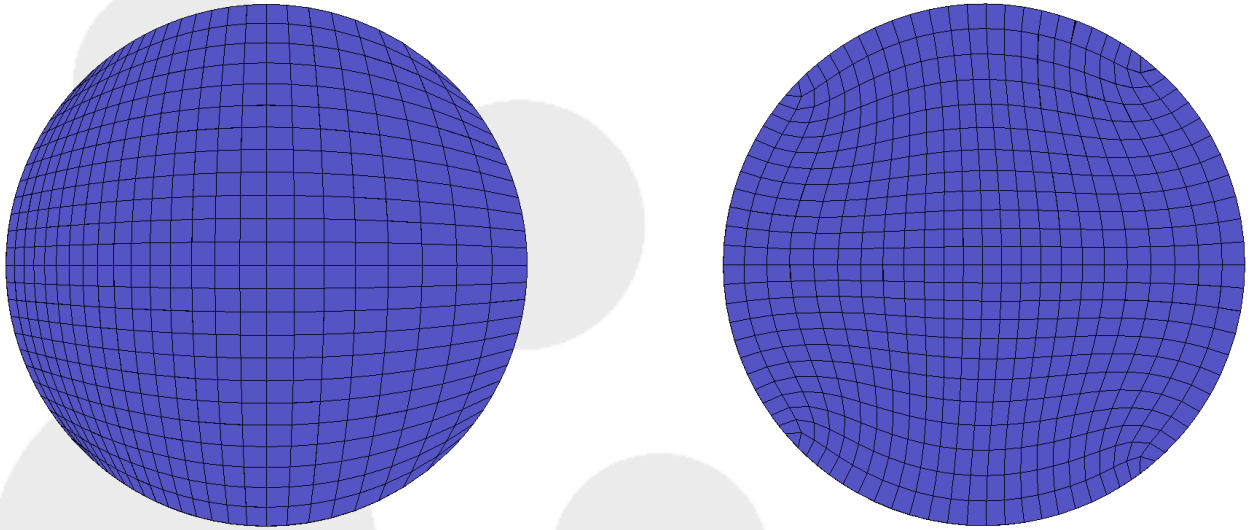
- Using LM-BFGS algorithm and Wolfe conditions for finding proper directions speeding up the algorithm

$$eta = -a_p \cdot H_p^{-1}$$



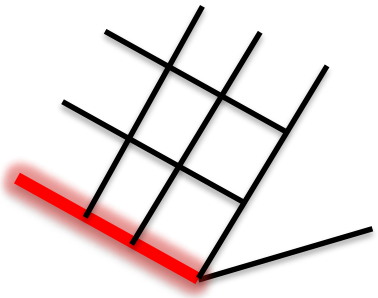
Methodology | Stage 7 | Optimisation

- Constrain boundary nodes to slide on the surface



Computational mesh before (left) and after (right) the optimisation algorithm with boundary nodes sliding in the surface

- Respect mesh feature edges



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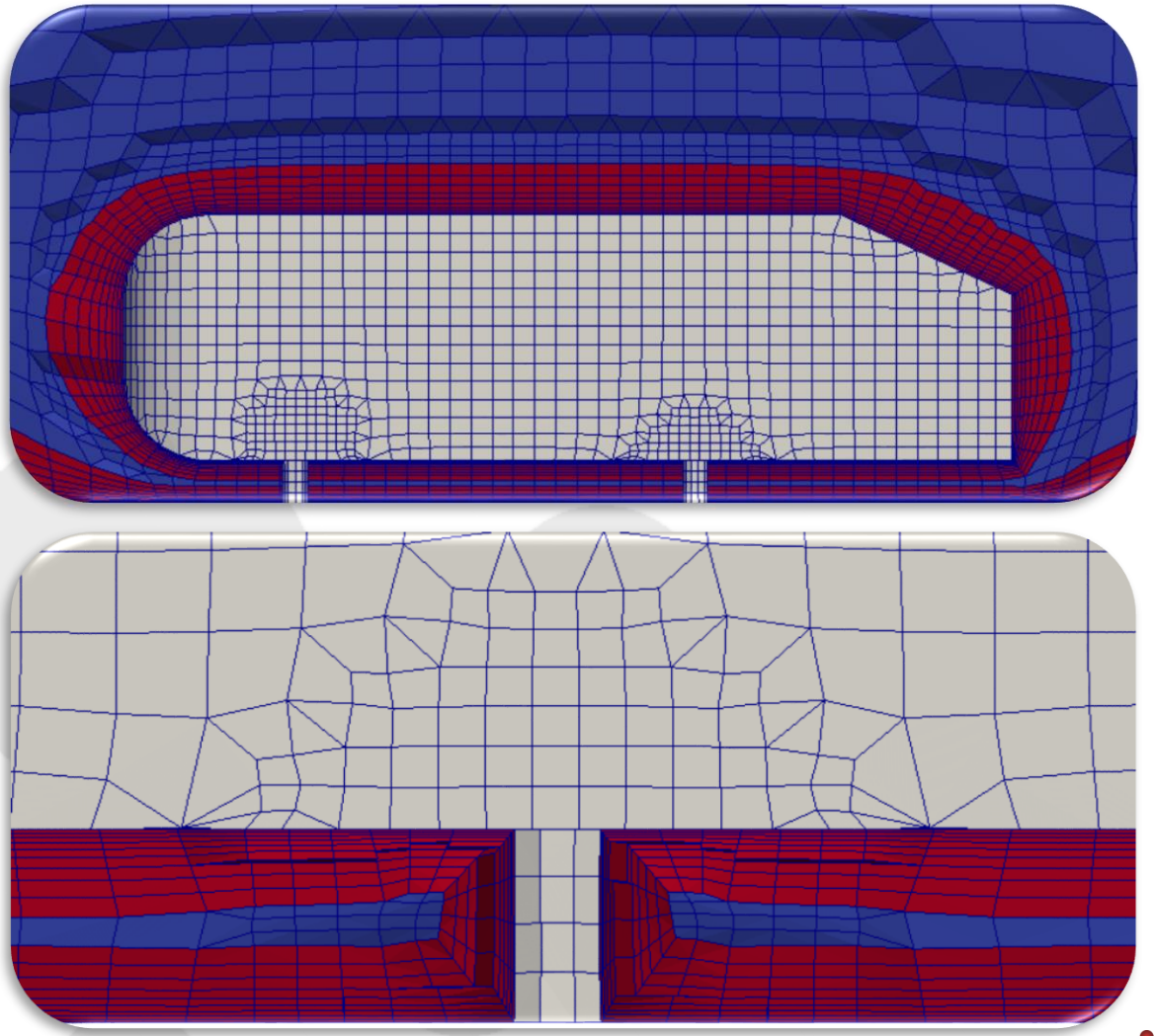
Examples | Ahmed

- Mesh on Ahmed Car 70k Cells and 9 layers



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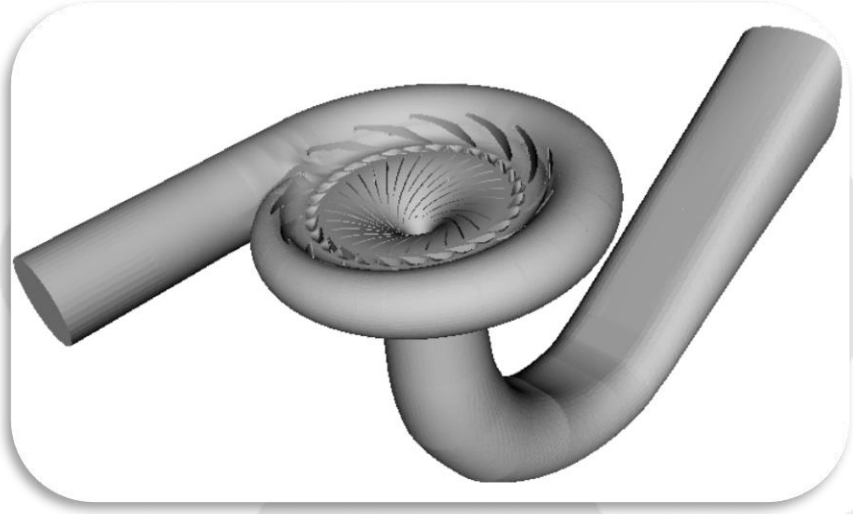
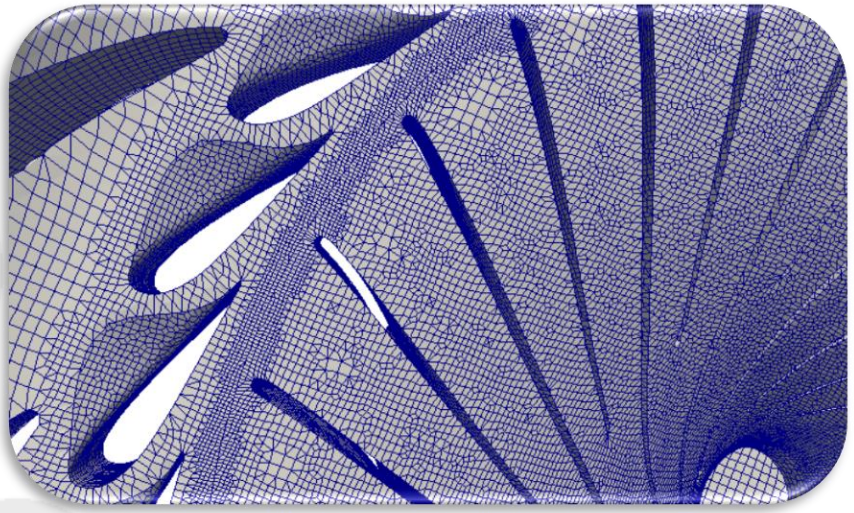
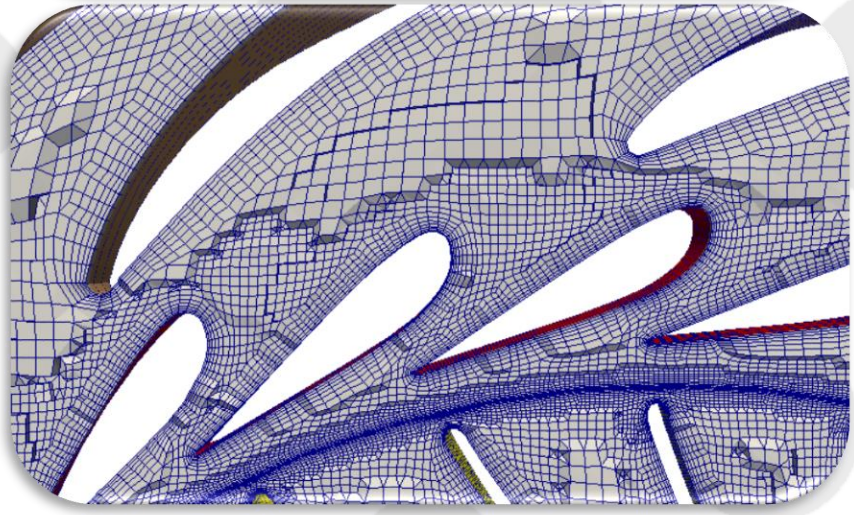
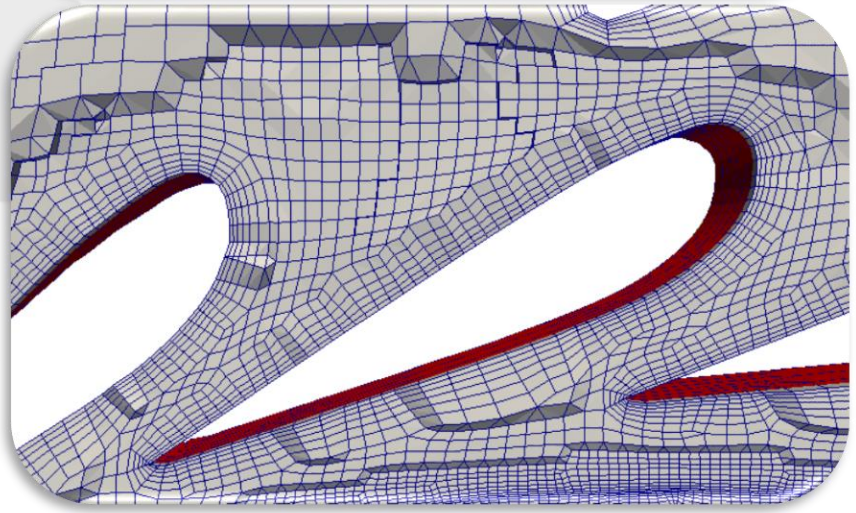
Examples | Francis99

- Francis99 pump case 5 million Cells with 6 surface layers









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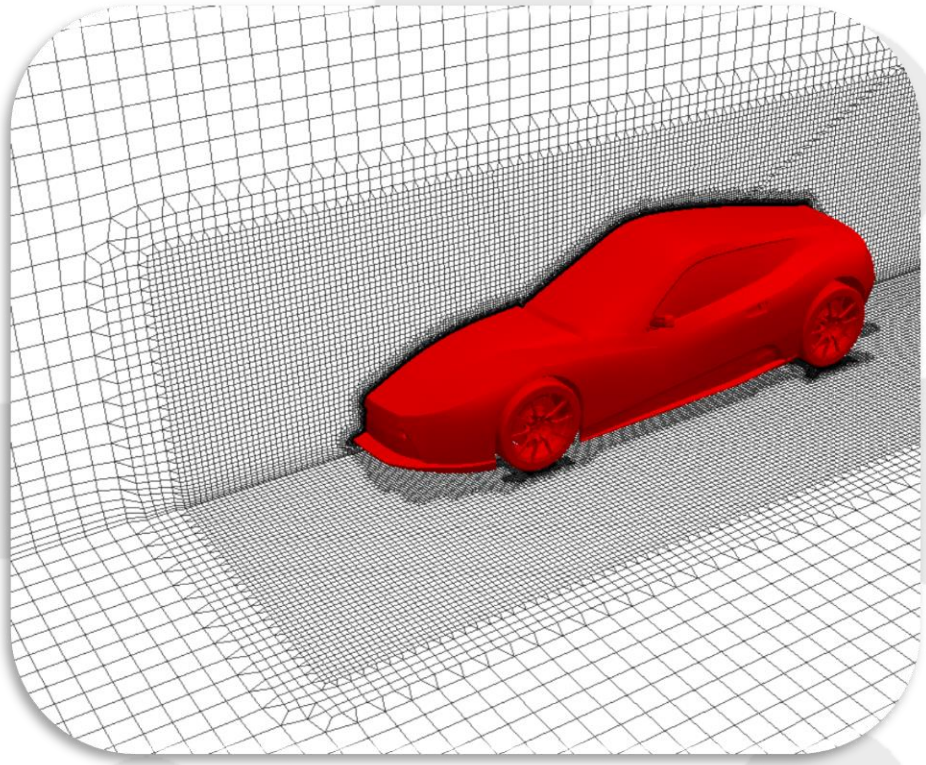
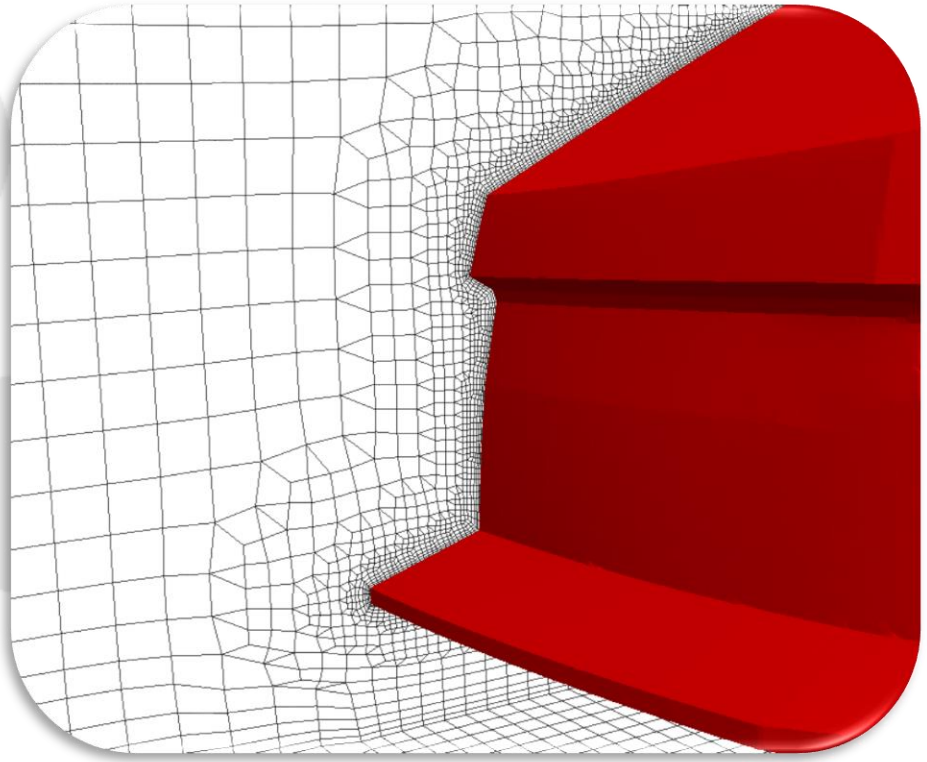
Examples | Electric Raceabout (ERA)

- ERA geometry (produced by Helsinki Metropolia University) with 18 million Cells and 5 surface layers





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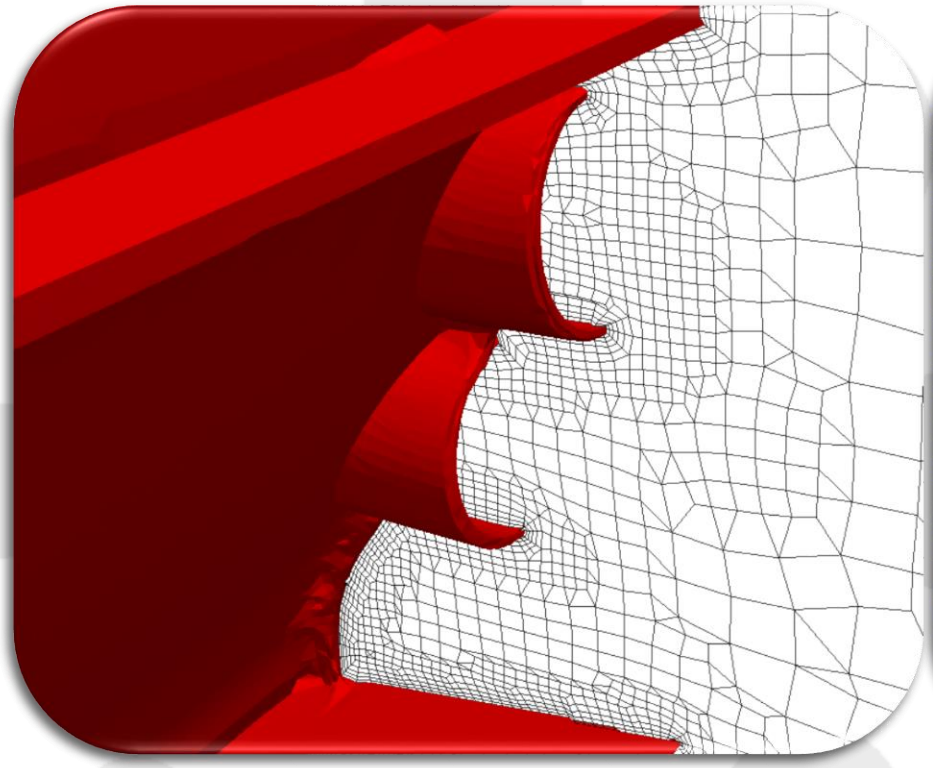
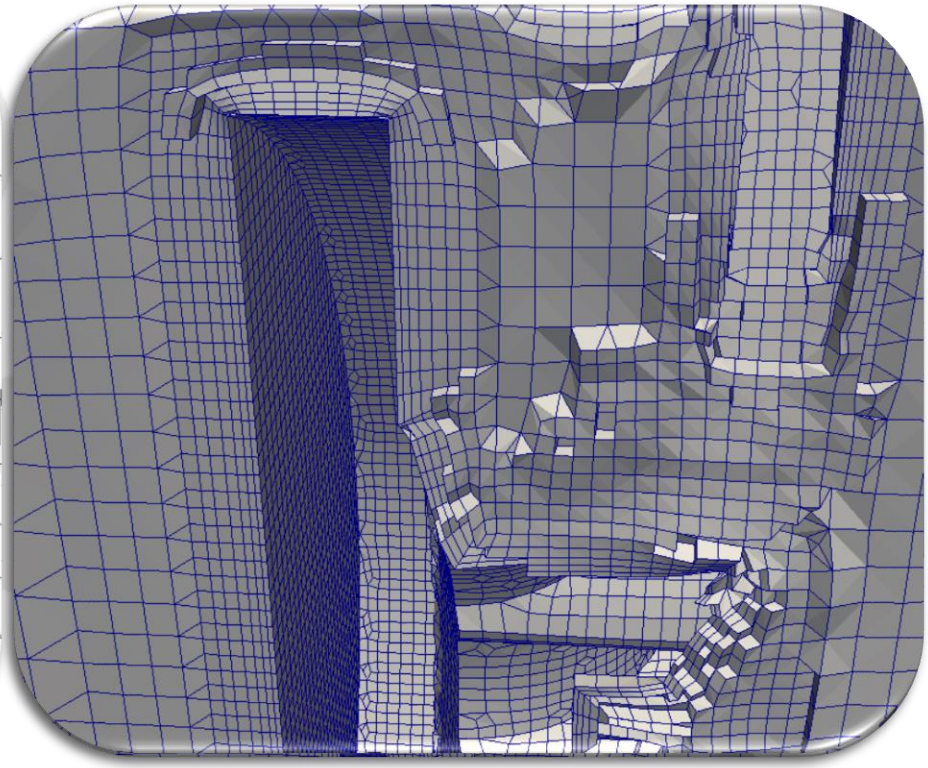
Examples | Electric Raceabout (ERA)

- ERA geometry : 18 million Cells with 5 surface layers





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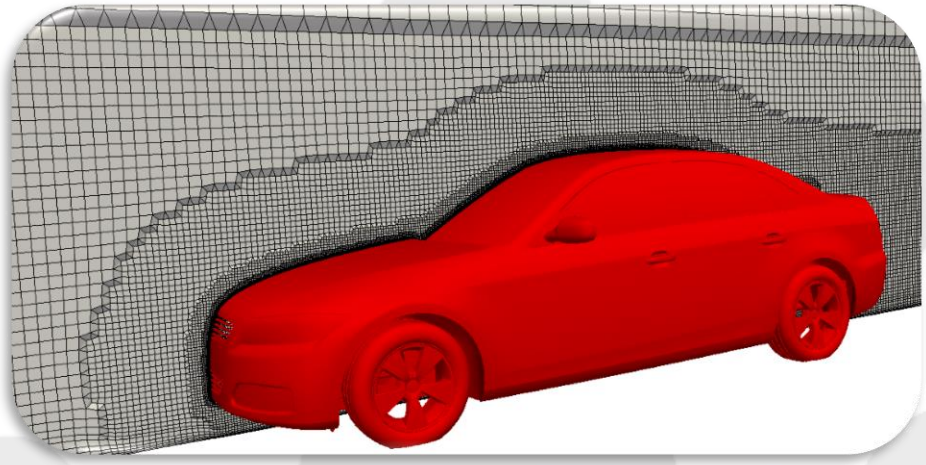
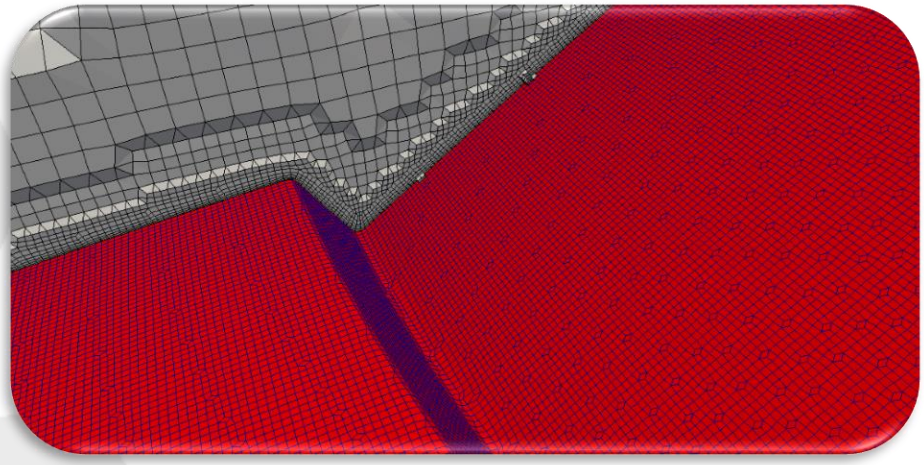
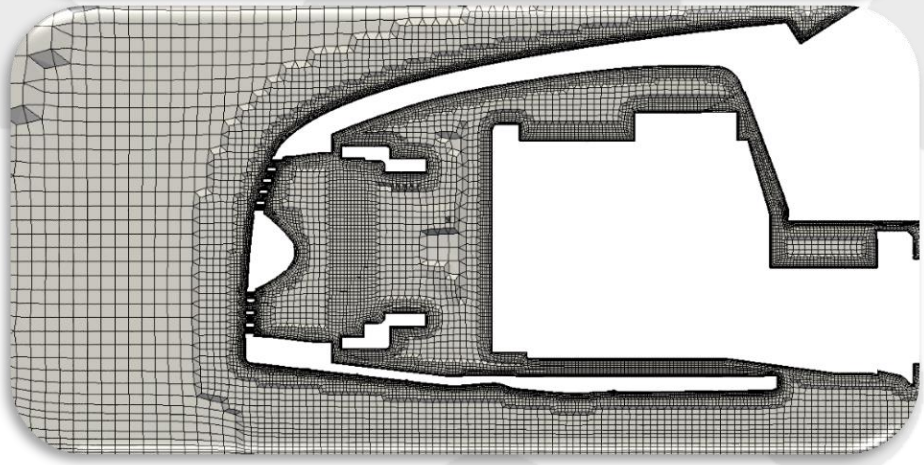
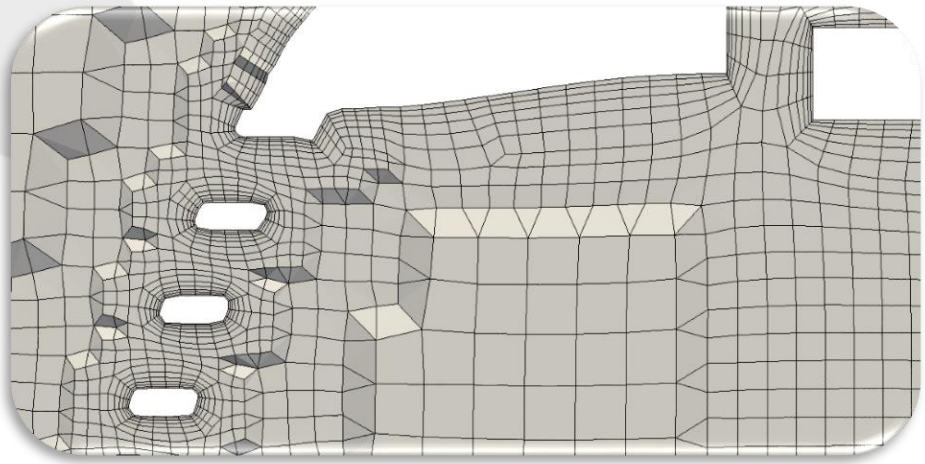
Examples | DrivAer

- DrivAer geometry (produced by TUM) with 37 Million Cells and 6 surface layers









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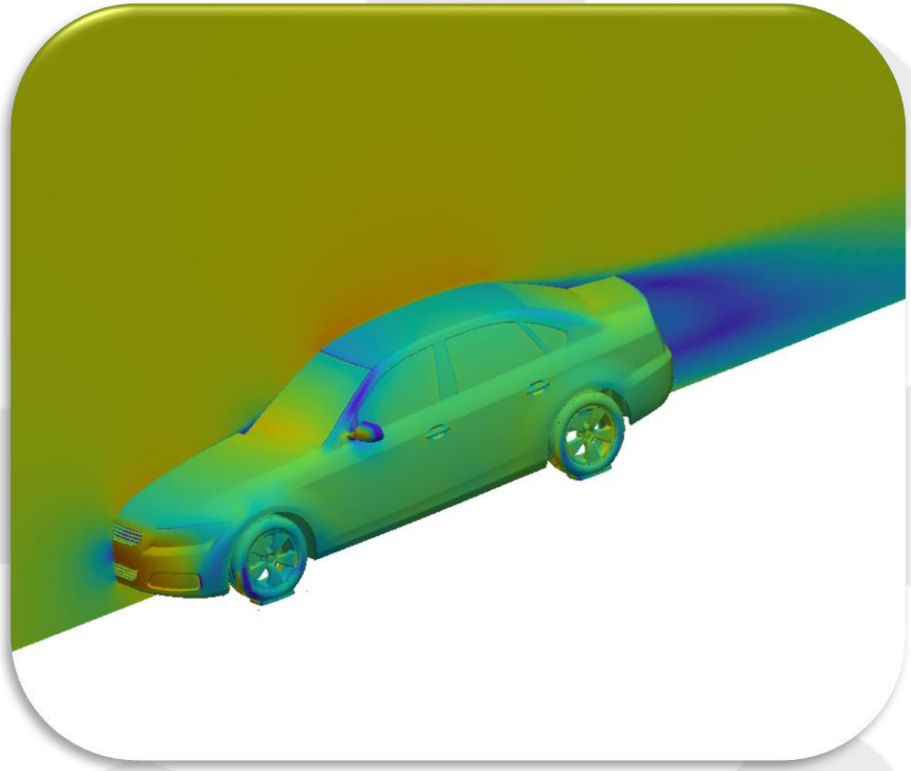
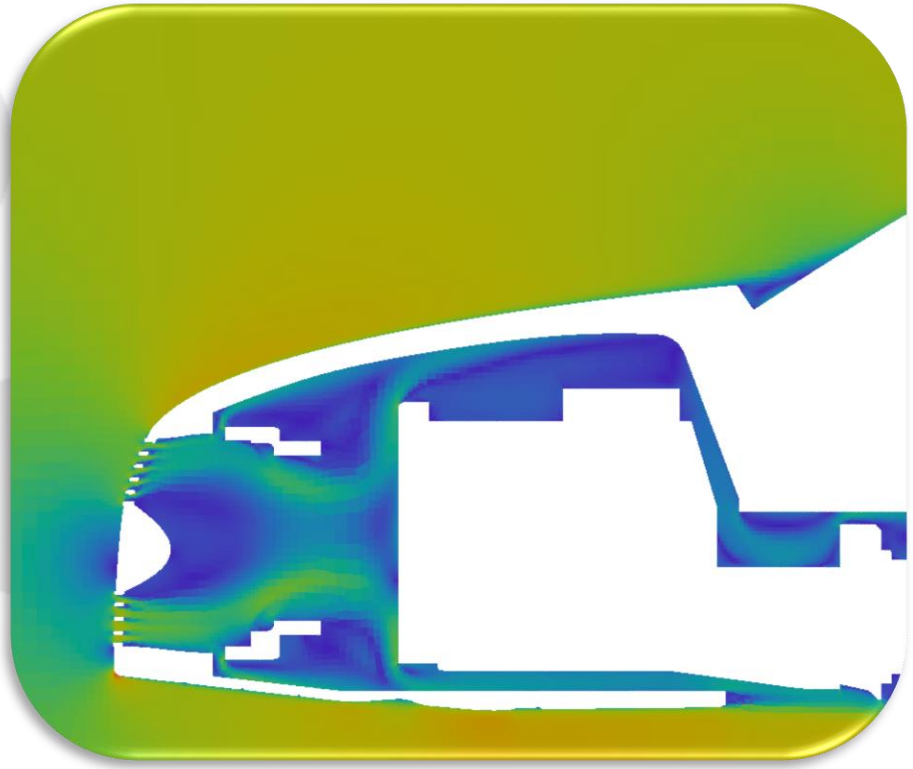
Examples | DrivAer

- RANS Spalart Allmaras solution on DrivAer





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Conclusions

- Initial prototype of new mesh generator has been developed
- Improvements to surface mesh quality and layer insertion over snappyHexMesh meshes
- Future work will concentrate on productionising the method
  - Parallelise
  - Improve performance of optimisation stage
  - Full support for zone creation

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