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iconCFD®
MESH & WRAP
Performance & Ease-of-use

With kind permission of:
Koenigsegg Automotive AB

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November 2016

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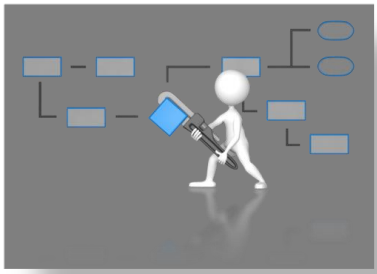
AGENDA

iconCFD® MESH & WRAP

- Introduction
- Performance
- Ease-of-use
- Conclusions



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INTRODUCTION
iconCFD® WORKFLOW

iconcfd

Modularized ● Industrialized ● Customized

iconCFD Process
- GUI
- MultiCase

iconCFD Wrap

iconCFD Mesh

iconCFD Cold
iconCFD Thermal
iconCFD Optimize
iconCFD VOF
iconCFD ... etc.

iconCFD Support & Documentation

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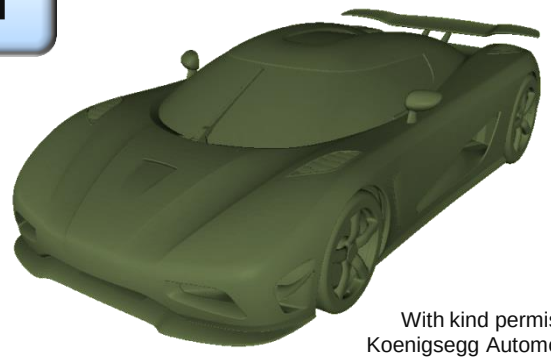
INTRODUCTION

iconCFD® MESH OVERVIEW

- Automatic hexahedral-dominant mesh generation
- Creation of meshes with guaranteed quality on highly complex industrial models
- Fully parallel meshing with dynamic load balancing
- Support for multiple volume regions with conformal or arbitrary grid interfaces

iconCFD® Mesh



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PERFORMANCE
HYBRID PARALLELISATION

Aims:

- Reduce memory requirements
- Exploit many-core cluster hardware
- Future-proof the mesh generator for next generation HPC architecture

Objective:

- Enable meshing using a combination of domain decomposition (inter-node) and multi-threading (intra-node)

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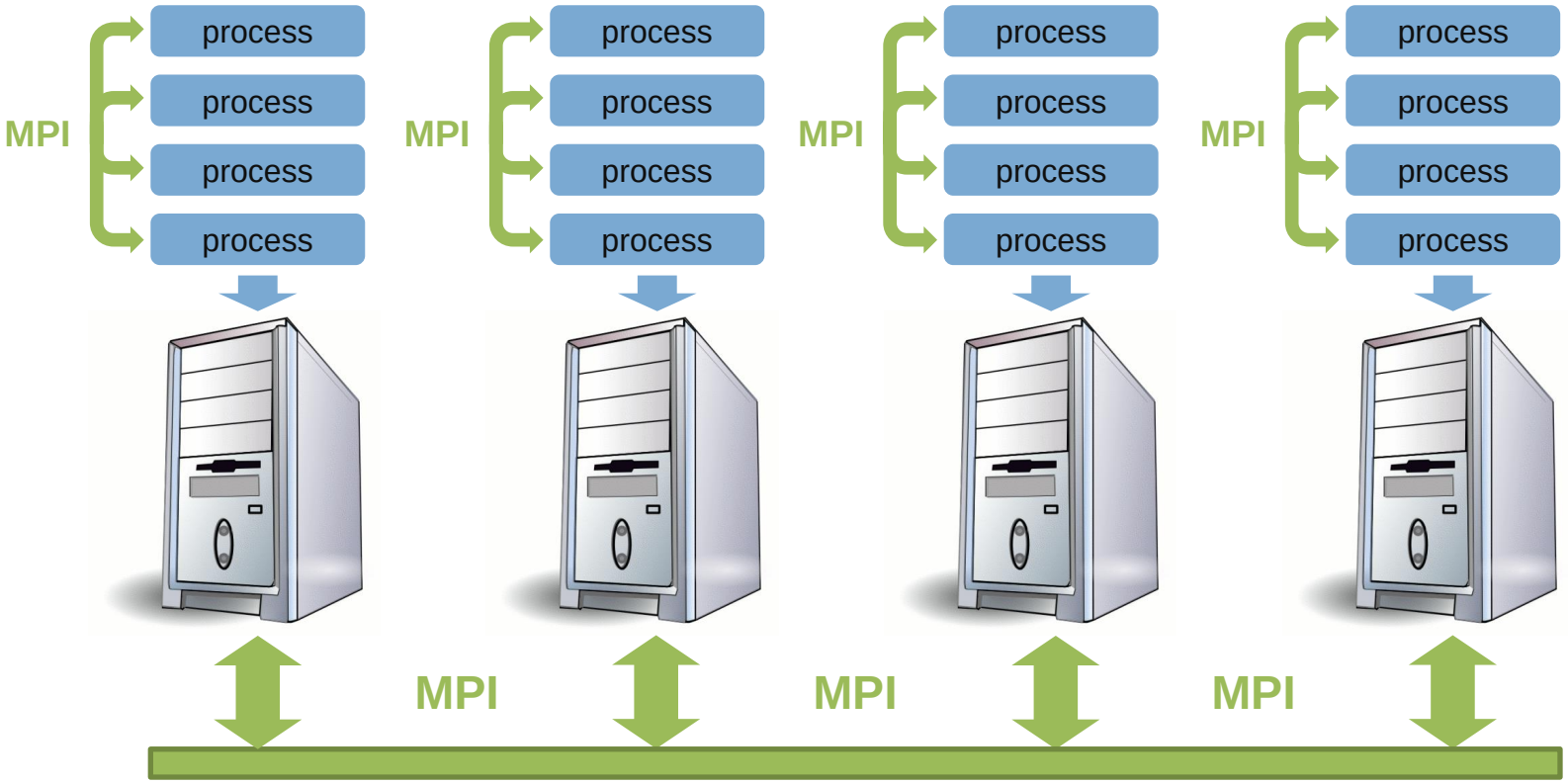
PERFORMANCE
HYBRID PARALLELISATION



Standard domain decomposition (no multi-threading)

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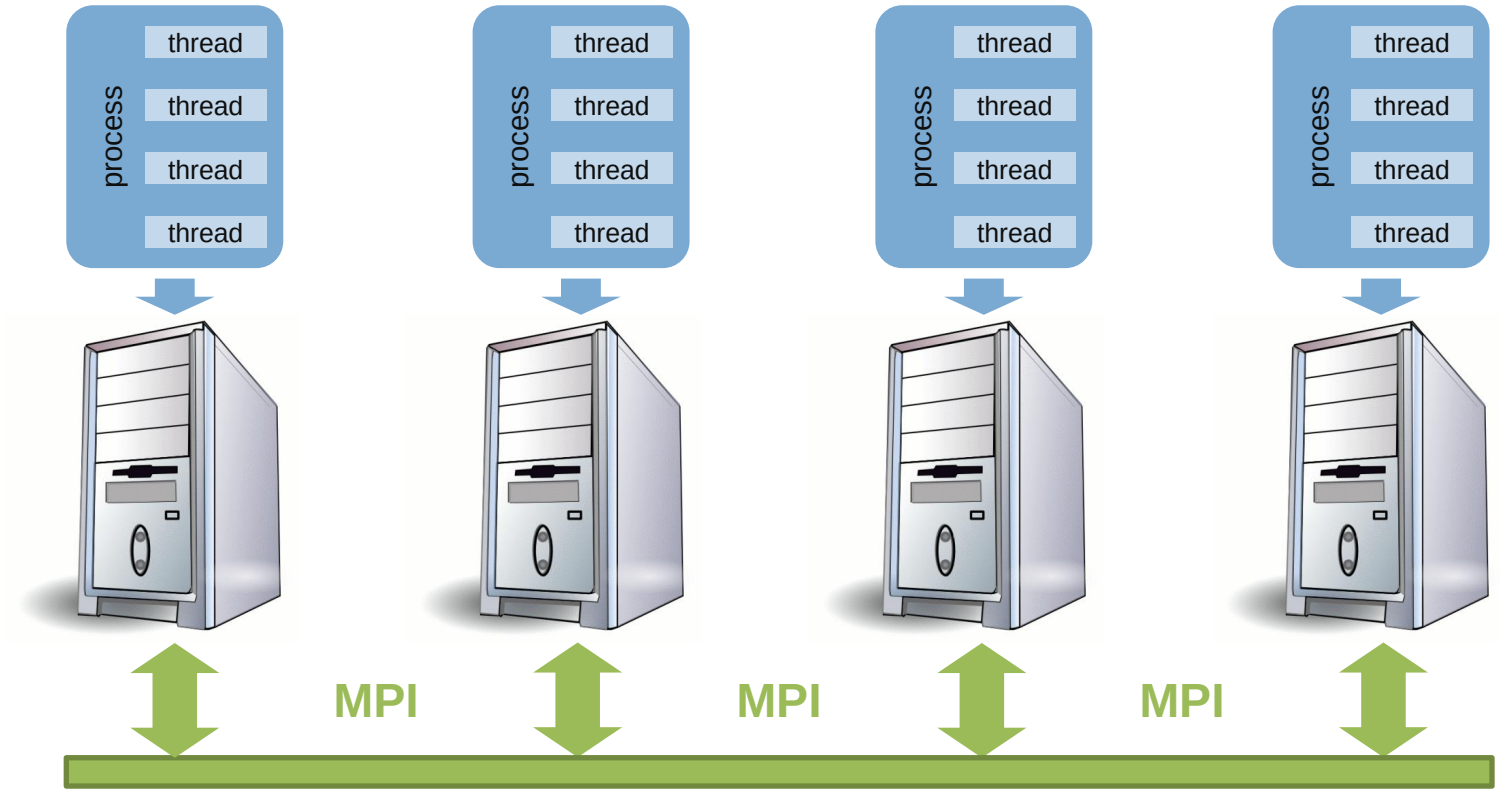
PERFORMANCE
HYBRID PARALLELISATION



Domain decomposition per node & multi-threading within node

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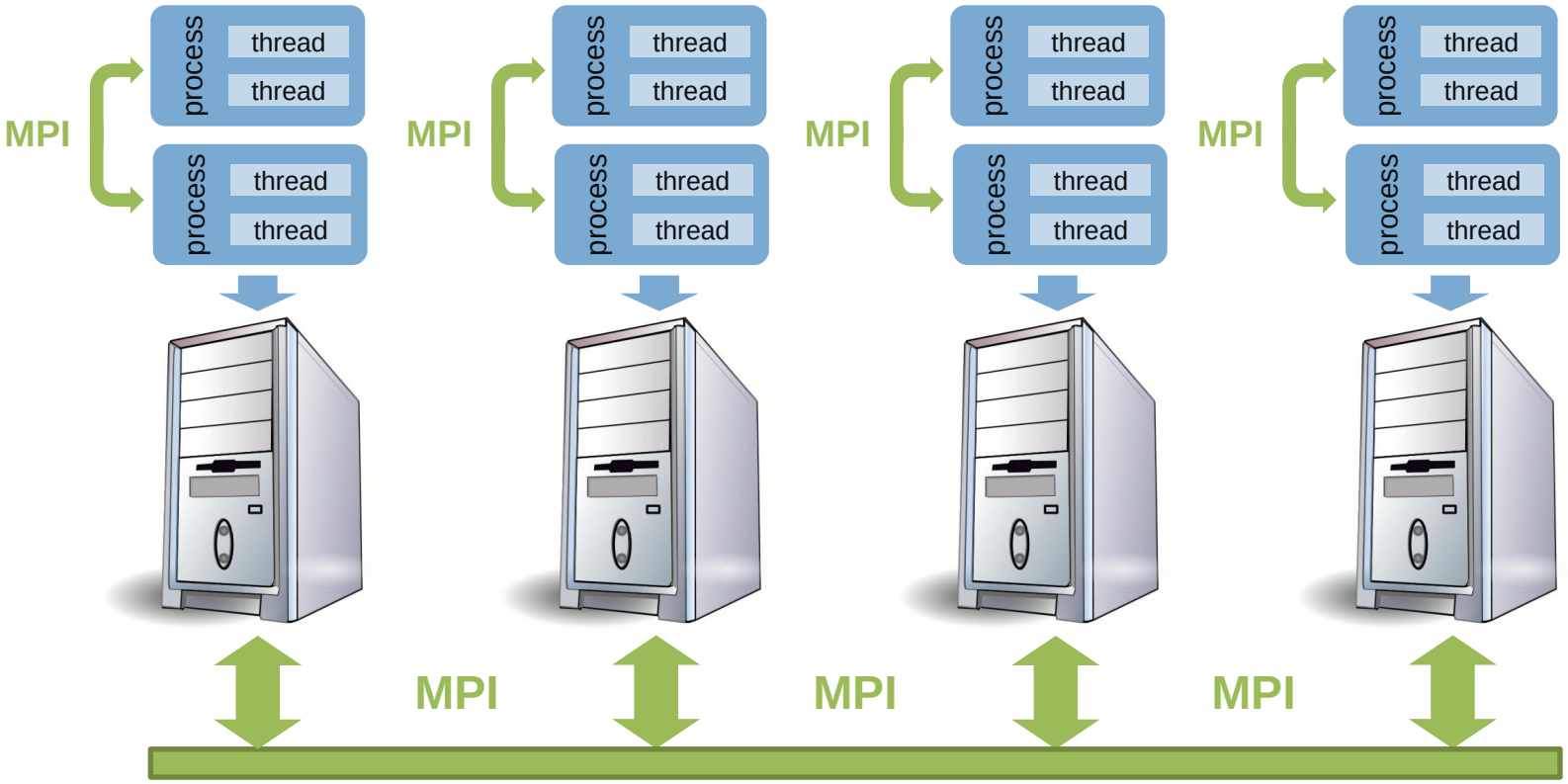
PERFORMANCE
HYBRID PARALLELISATION



Combined domain decomposition & multi-threading

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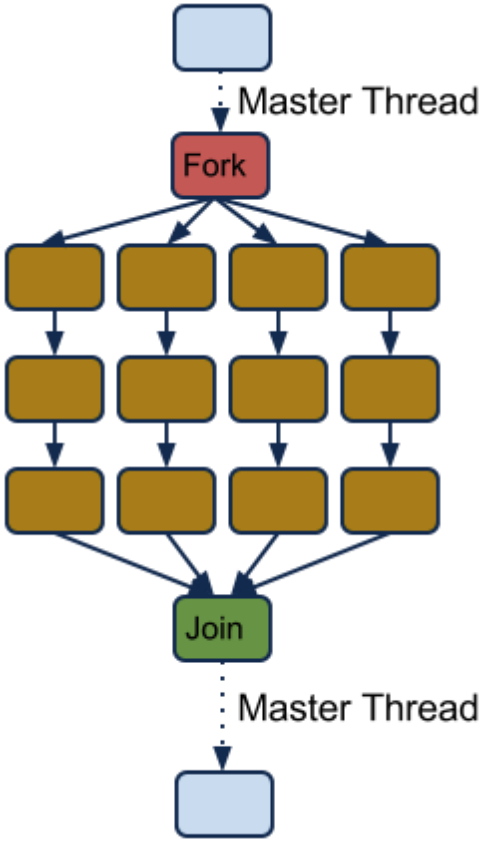
PERFORMANCE
HYBRID PARALLELISATION

Implementation:

- Using “fork-join” multi-threading model
  - Multi-threading can be added progressively
- Added OpenMP directives to:
  - All mesh quality checks
  - Mesh topology relations
  - Cell and face quantities (e.g. cell centre & cell volume calculations
  - Mesh smoothing routines



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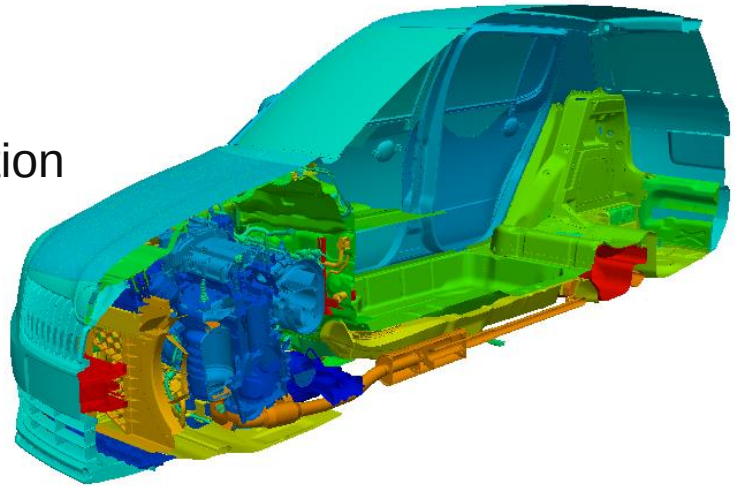
PERFORMANCE
HYBRID PARALLELISATION

Testing:

- Mesh generated for industrial automotive case (Skoda Fabia II):
  - 30 million cells
- Combination of domain decomposition & multi-threading on cluster:
  - 64 processes x 1 thread
  - 32 processes x 2 threads
  - 16 processes x 4 threads
  - 8 processes x 8 threads

Geometry courtesy of Škoda Auto



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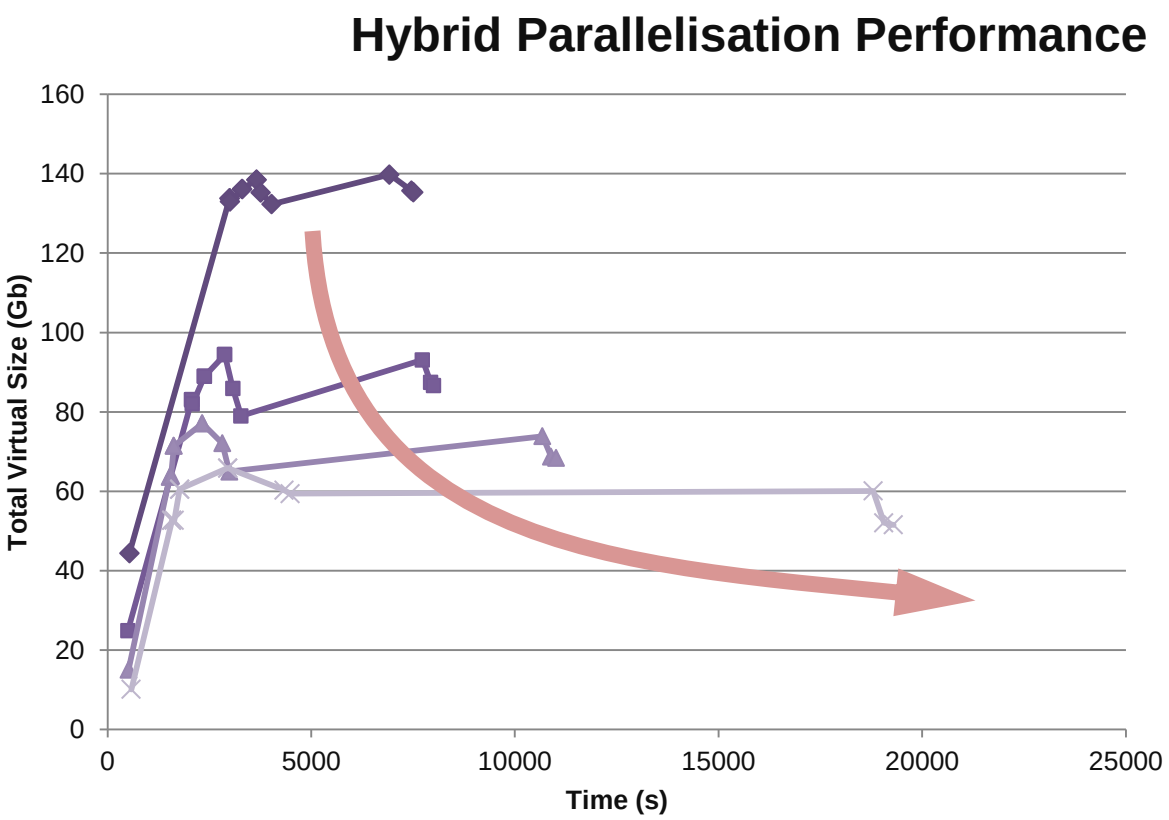
PERFORMANCE
HYBRID PARALLELISATION



Increasing number of threads per core:

- reduces peak memory
- increases runtime

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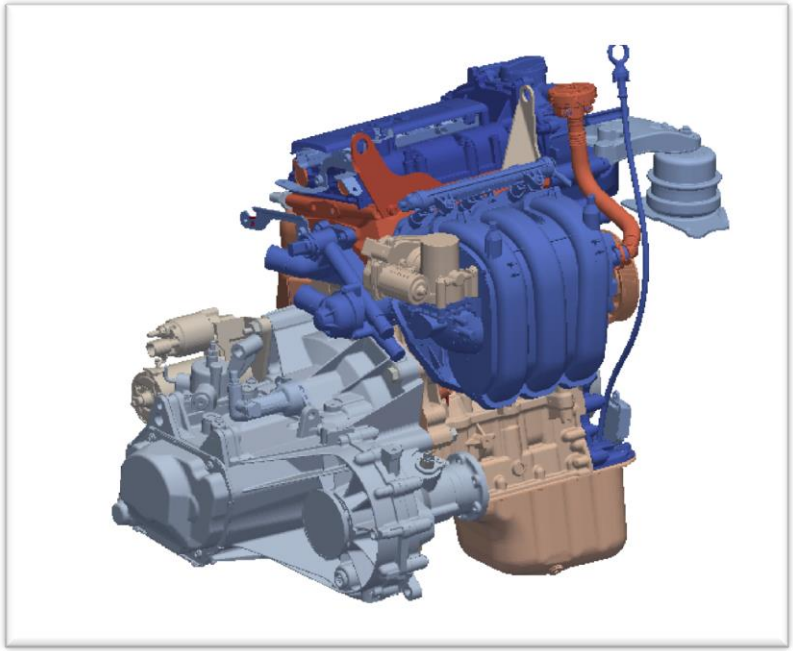
EASE-OF-USE
MOTIVATION

- Major bottleneck in mesh generation:
  - original CAD → watertight geometry representation

- Translation of geometry from native CAD results in:
  - Missing or duplicate parts
  - Small gaps or overlaps

- Resolving geometry issues
  - Labour-intensive
  - Time-consuming

Geometry courtesy of Škoda Auto



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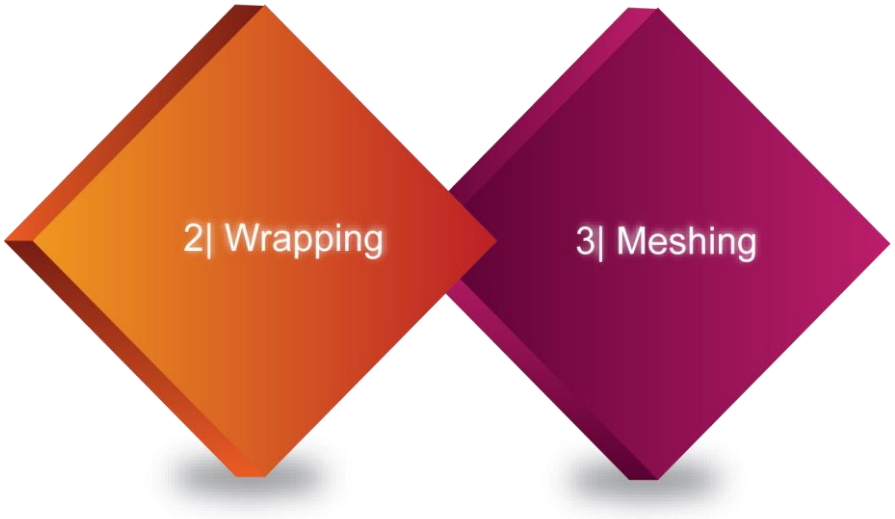
EASE-OF-USE
AIM

- Integrated approach to wrapping and mesh generation
  - Exploit existing adaptively-refined Cartesian grid generator
  - Simultaneously perform wrapping and meshing
  - Handle large gaps in model assemblies
  - Avoid re-sampling geometry



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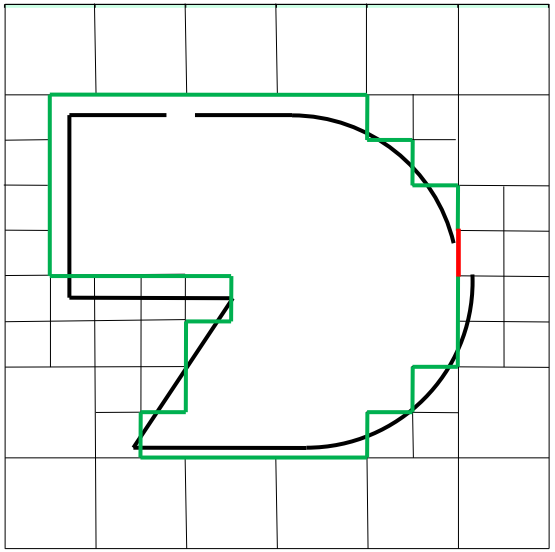
EASE-OF-USE
BACKGROUND

- Process of identifying fluid region:



a) Geometry with gaps and refined mesh
b) Boundary faces (green)
c) Intersecting cells (red)
d) Cells connected to keep point (green)
e) Re-assignment of intersecting cells to keep region
f) Mesh corresponding to fluid domain

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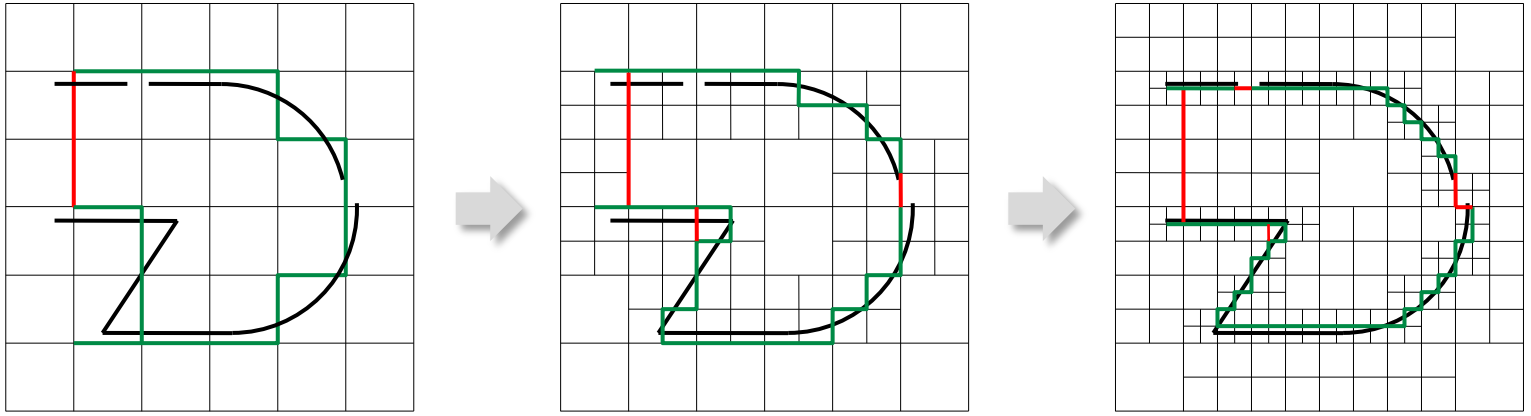
EASE-OF-USE
COMBINED WRAPPING & MESHING

- **Current meshing process**
  - ✓ Tolerant of small gaps (geometry is wrapped at finest mesh level)
  - × Doesn't handle large (fully-resolved) gaps
- **Solution:**
  - Perform wrapping at coarser refinement levels:



Refinement level 1 | Refinement level 2 | Refinement level 3

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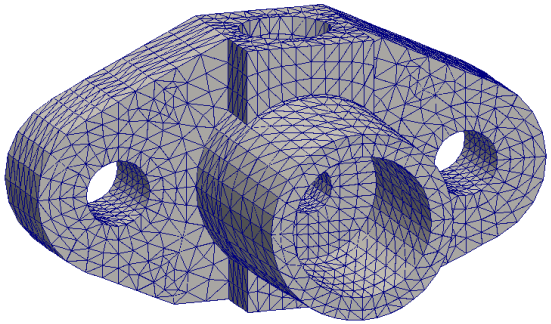
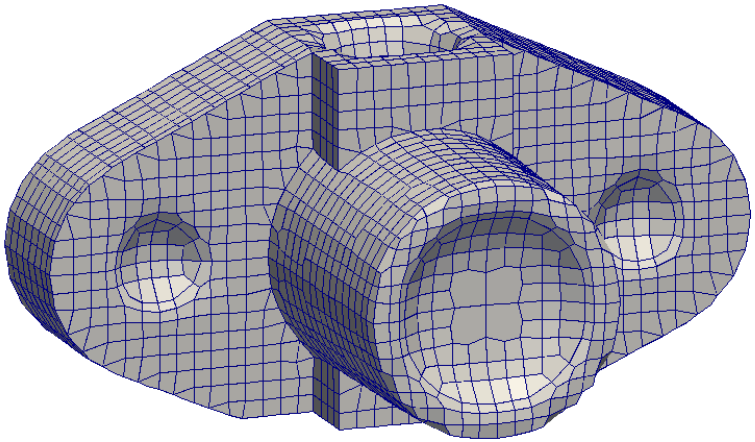
RESULTS
FLANGE

- Flange geometry from OpenFOAM® tutorial
- Initial uniform Cartesian mesh created enclosing the geometry
- The iconHexMesh mesh generator is then used to apply 4 levels of surface refinement





Result at wrap level = 2

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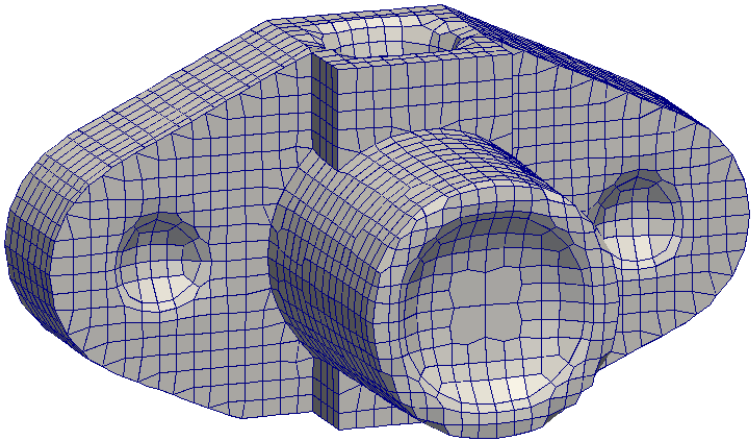
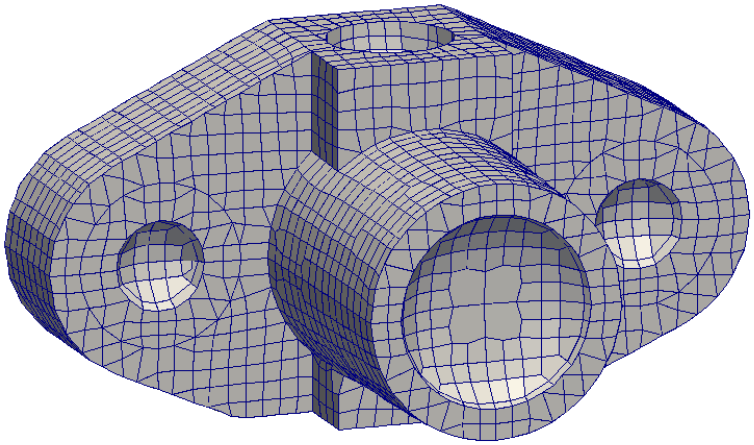
RESULTS
FLANGE

- Existing meshing functionality can be exploited to improve the capture of geometry features



Wrapped surface with basic surface snapping



Wrapped surface with feature line snapping

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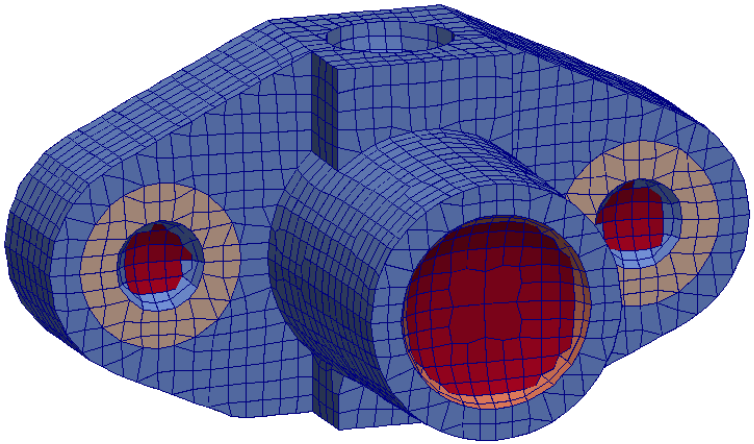
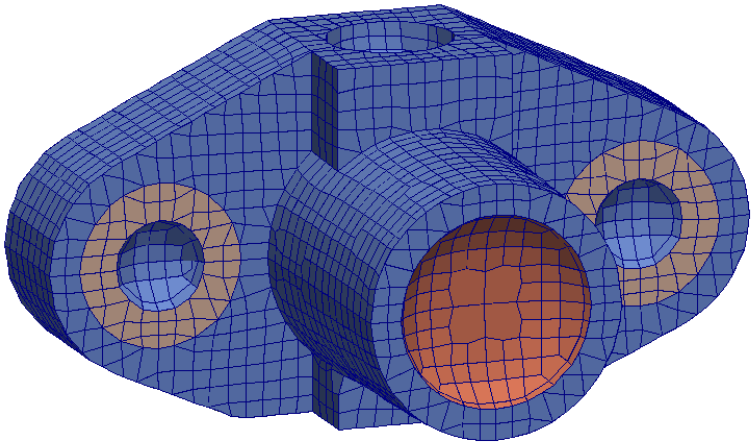
RESULTS
FLANGE

- Faces which close off holes in the geometry (gap faces) can be assigned to a separate patch or to neighbouring patches:



Gap faces (red) assigned to separate patch



Gap faces assigned to neighbouring patches

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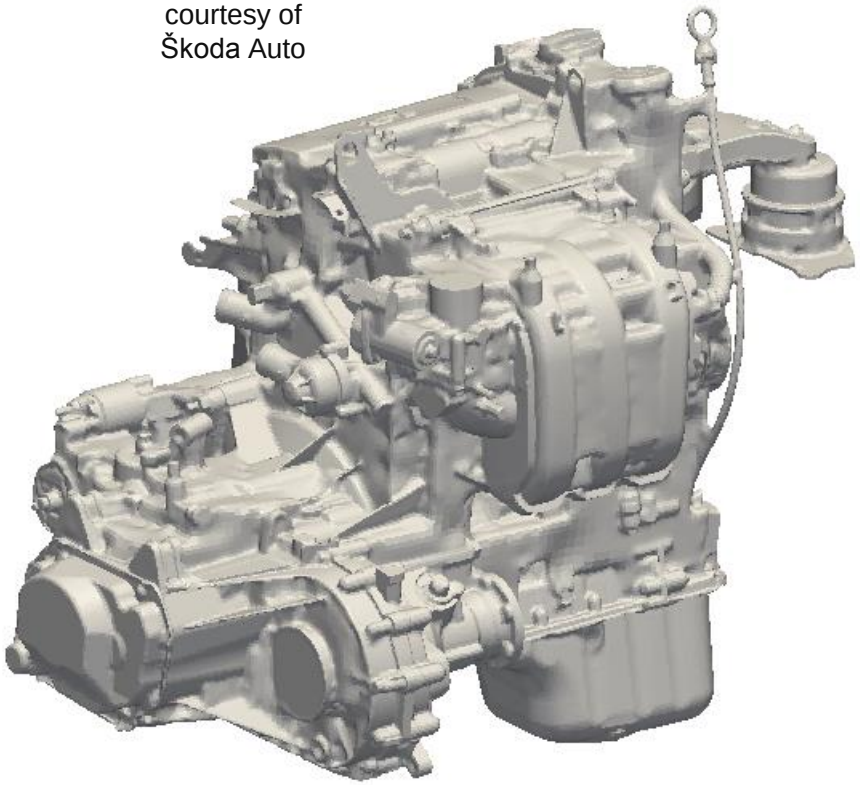
RESULTS
ENGINE BLOCK

- Highly detailed engine block
- Initial Cartesian mesh created with element size of 1.25m
- Uniform surface refinement of level 9 applied to engine
  - Small element size of 2.4mm
- Wrap level of 5 applied
  - Close holes < 40mm Ø
- Wrapping process took 278s
  - 2 Intel Xeon X5650 (2.67GHz) processors

Geometry courtesy of Škoda Auto



Wrapped surface:
Single closed manifold surface
762,028 triangles

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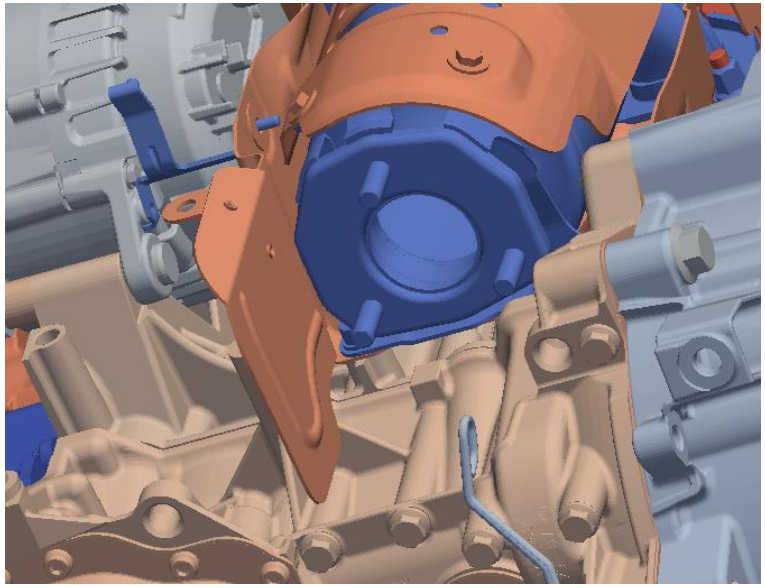
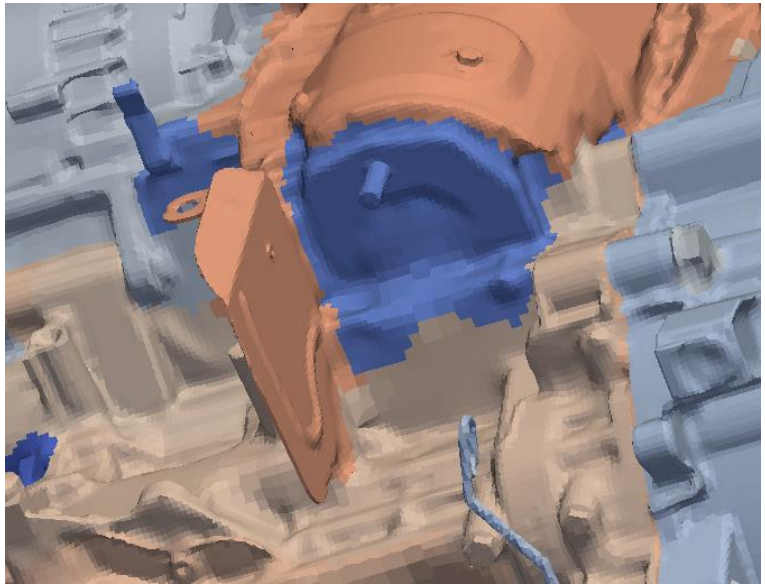
RESULTS
ENGINE BLOCK

- Wrapping is able to close large holes in geometry, whilst still capturing fine details:



Engine geometry



Wrapped surface

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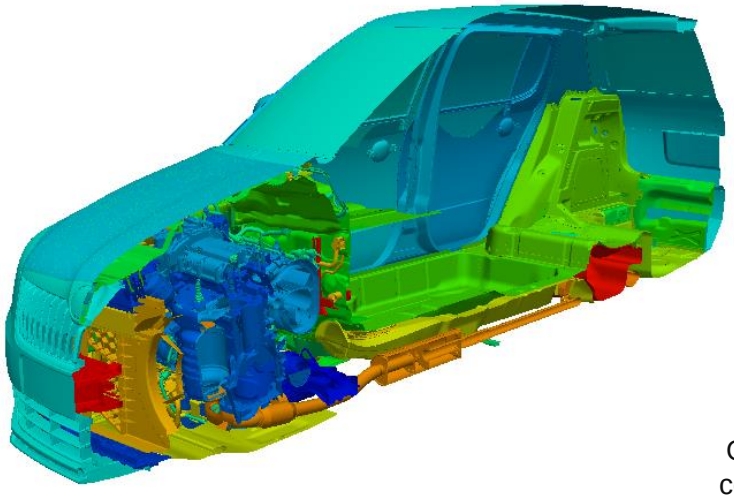
RESULTS
UHTM CASE

- Detailed model of Skoda Fabia II including:
  - electrical components
  - exhaust system
  - cooling
  - power-train
  - suspension
- 14 STL files:
  - 382 solids
  - 36 million triangles



Geometry courtesy of Škoda Auto

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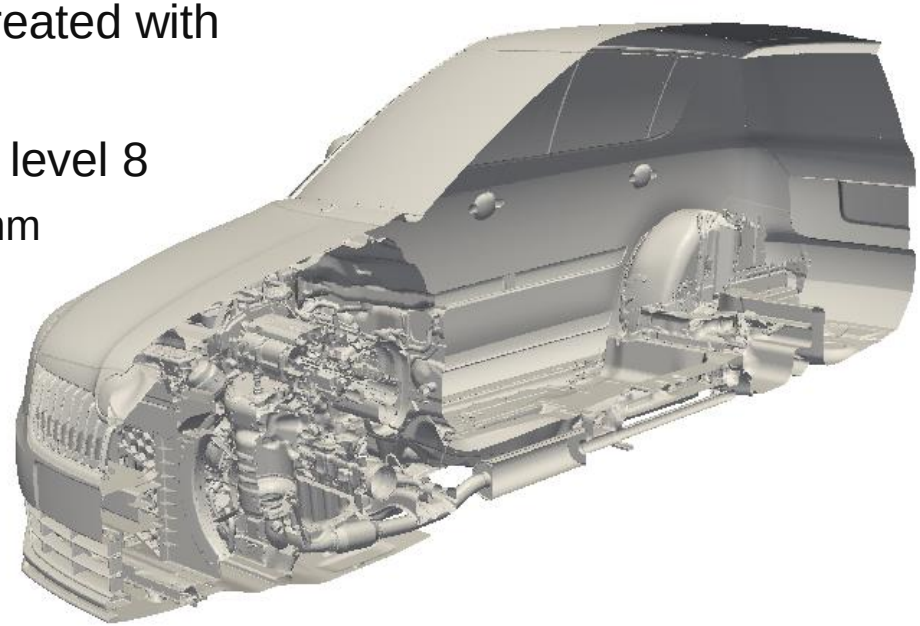
RESULTS
UHTM CASE

Geometry courtesy of Škoda Auto

- Initial Cartesian mesh created with element size of 0.625m
- Surface mesh refined to level 8
  - Element size of 2.44mm
- 2 levels of curvature refinement applied
- Wrap level of 4
  - 40mm hole size
- Complete process:
  - Completed in 2h 42m
  - 32 cores with Intel Xeon E5-2670 (2.60GHz) processors



Wrapped surface: 12.5M triangles

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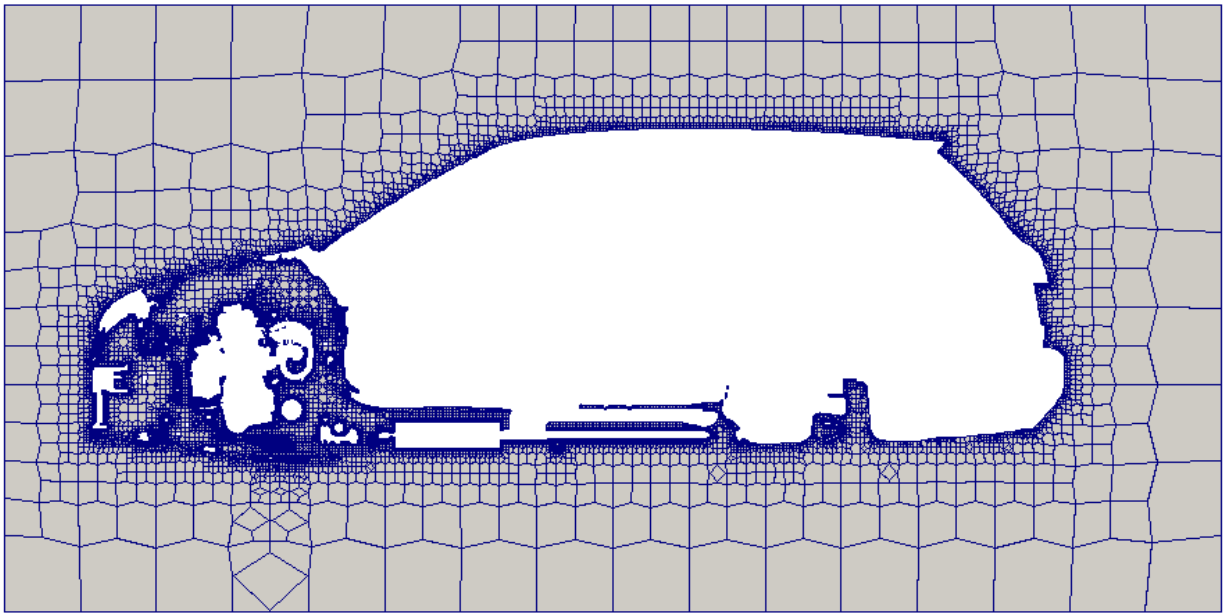
RESULTS
UHTM CASE

Background mesh with wrapping activated



Geometry courtesy of Škoda Auto

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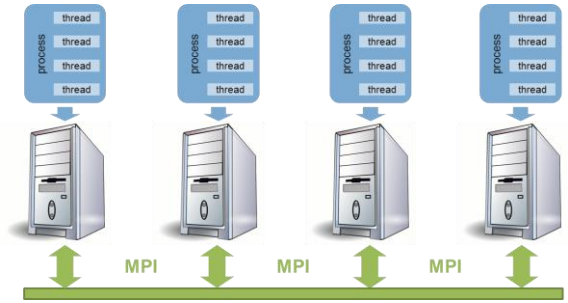
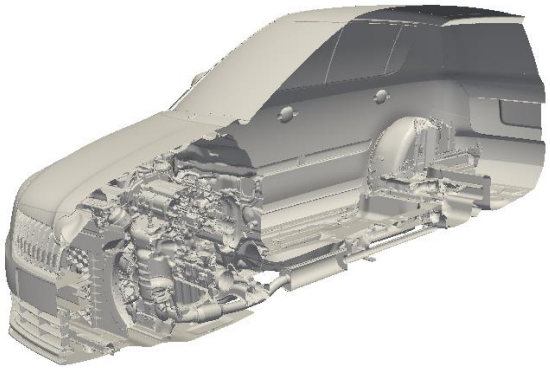
iconCFD® Mesh & Wrap
CONCLUSIONS

- Domain decomposition and multi-threading can be effectively combined when meshing with iconCFD Mesh to fully exploit multi-core hardware architectures.



- Wrapping functionality can be employed directly within the iconCFD mesh generation utility to handle poor quality input geometry without labour-intensive CAD repair, and without sacrificing geometry fidelity.



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ACKNOWLEDGEMENTS

The authors would like to thank Skoda for their kind permission to use the Fabia II vehicle geometry.

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