Human Body Models Customization by Advanced Mesh Morphing: Parametric THUMS

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THUMS User Community Meeting

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THUMS User Community

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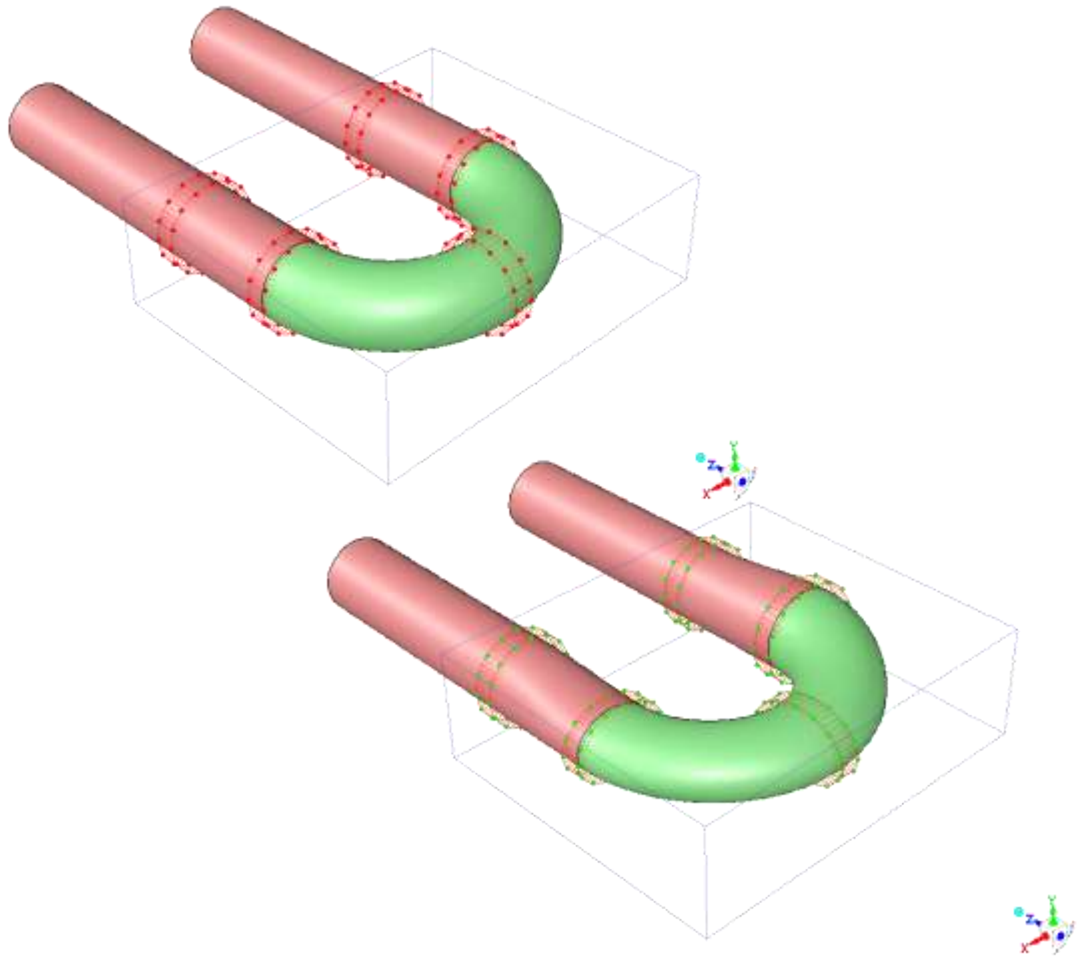
Shape parameterization strategy

- Geometric parameterization by **mesh morphing**
- The principle is to take the control on a set of point and to transfer the deformation to the whole mesh
- A new shape of the CAE model ready to run
  - for structural analysis in the FEA solver
  - for flow analysis in the CFD solver



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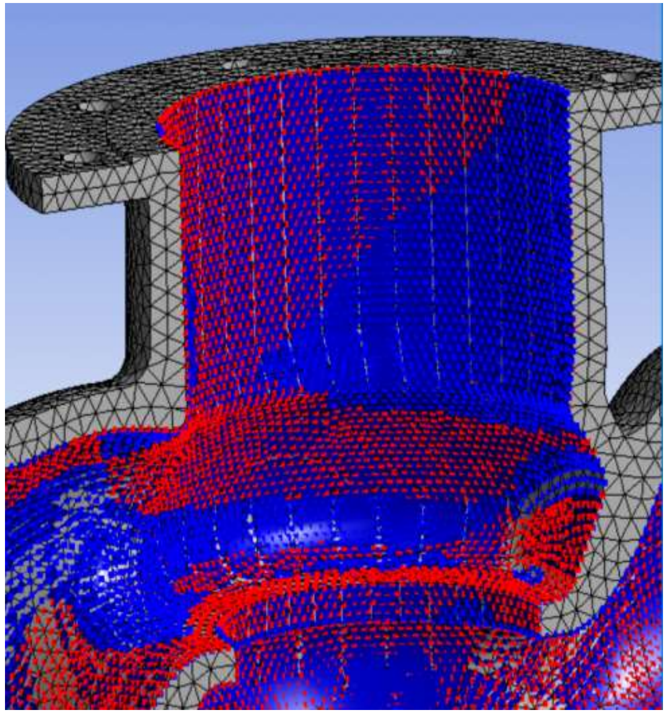
Radial Basis Functions mesh Morphing

- We adopt Radial Basis Functions (RBF) to drive mesh morphing (smoothing) from a list of source points and their displacements
  - Surface shape changes
  - Volume mesh smoothing
- RBF are recognized to be one of the **best mathematical tool** for mesh morphing



$$\begin{cases} s_x(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^x \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) \\ s_y(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^y \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) \\ s_z(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^z \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) \end{cases}$$

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Radial Basis Functions mesh Morphing

- No re-meshing
- Can handle any kind of mesh
- Can be integrated in the CAE solver (FEM/CFD/FSI)
- Highly parallelizable
- Robust process
- The same mesh topology is preserved (adjoint/ROM)
- CAD morphing (iso-brep)

www.rbf-morph.com

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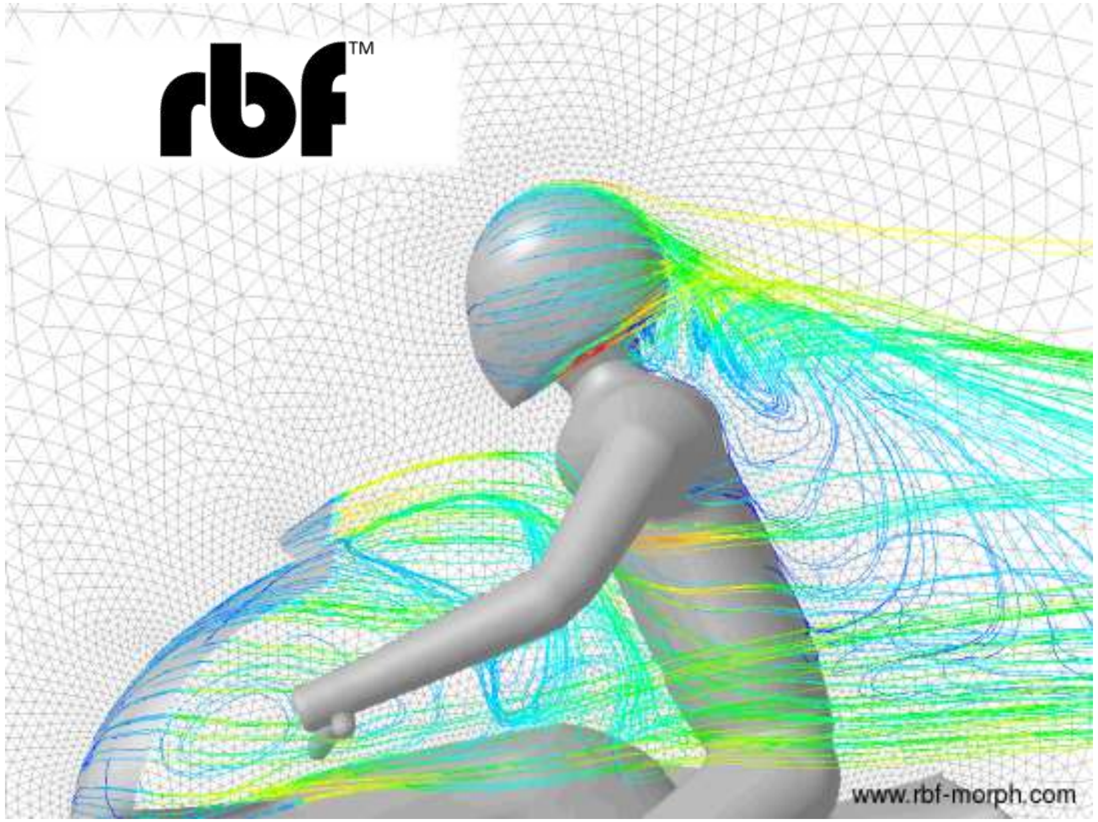
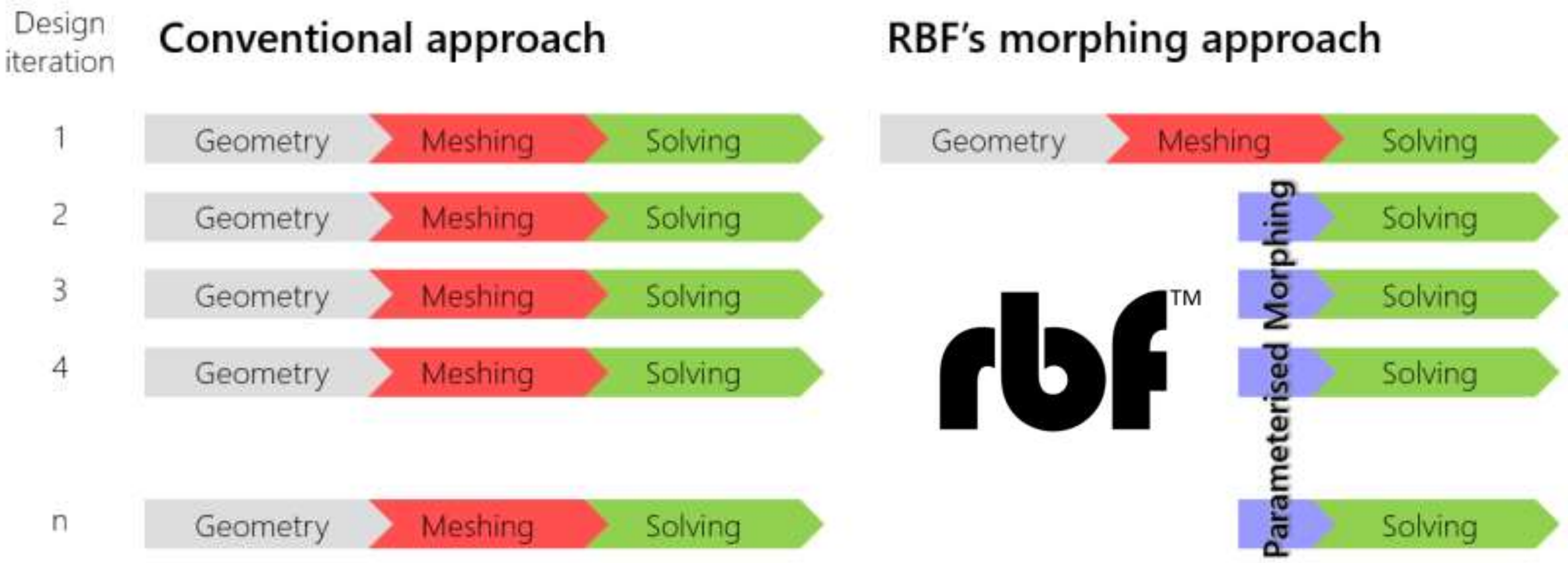
We make CAE models parametric

- RBF Morph makes the CAE model **parametric**
- Shape parameters are driven by **an orchestrator**
- Shape parameters can be used to generate snapshots for real time Digital Twins (ROM/AI)



We make CAE models parametric

- Morphing is a **key enabler** for optimization and Digital Twins
- The turnaround time of the optimization is usually **reduced by a factor five** (weeks becomes days)



Interactive Digital Twins

- High-fidelity simulations big data for training AI models:
  - Design stage: steer new projects more effectively
  - Operation stage: **real-time** interactions are key enablers of digital twins
- Challenges:
  - High level of automation required
  - Replicable, easily deployable workflow
- We present a comprehensive solution based on CAE tools and FMI standard, powered by **Unity rendering** and exported to **Meta Quest 3** AR/VR

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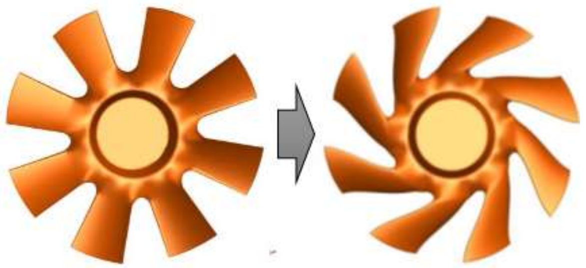
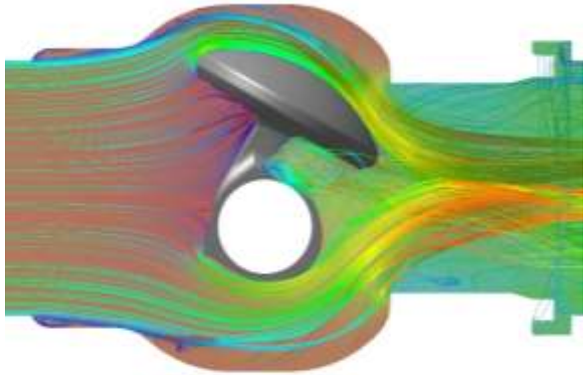
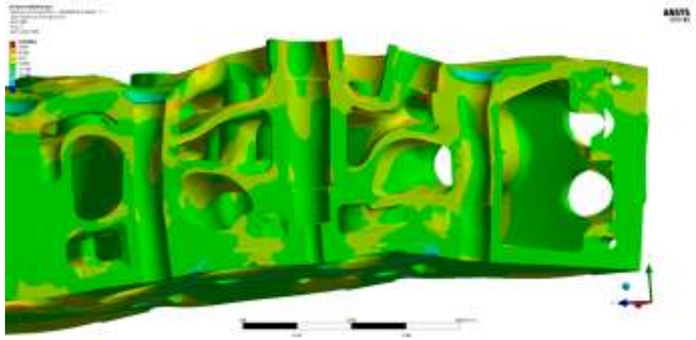
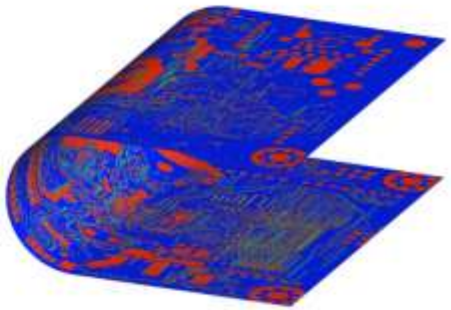
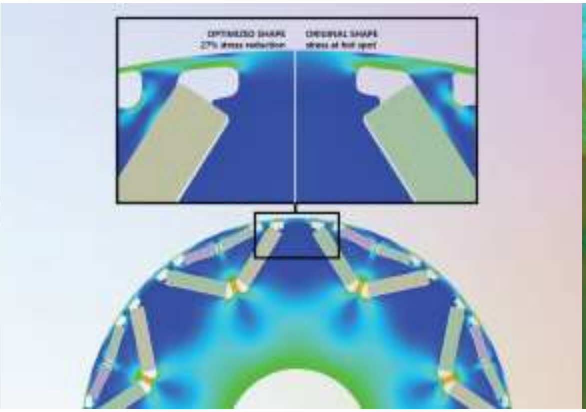
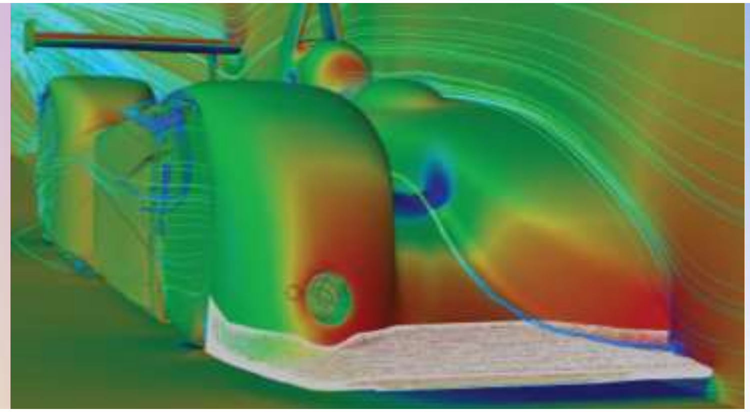
Applications

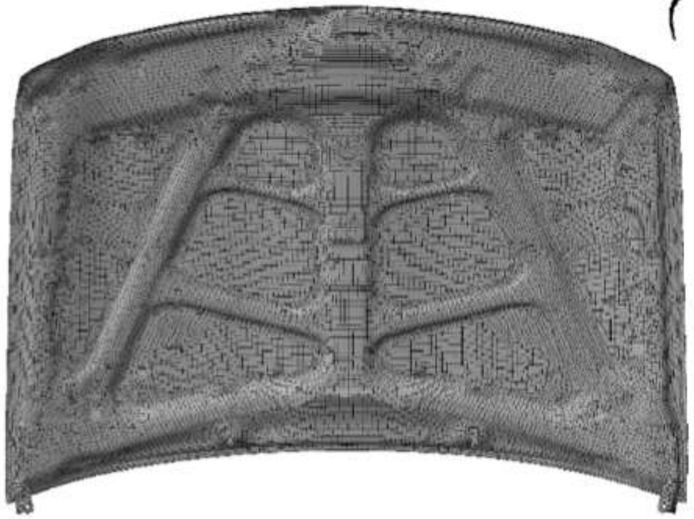






Reusing the LS-DYNA model of a different car

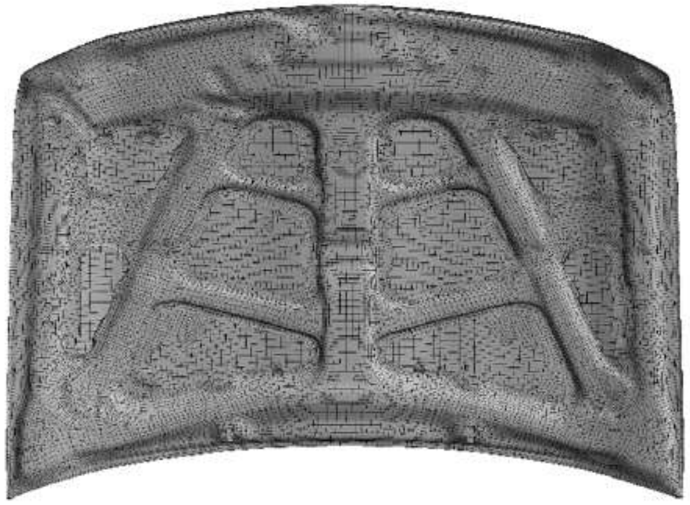
Honda Accord
starting mesh

Morphing onto the style (parameter-free)

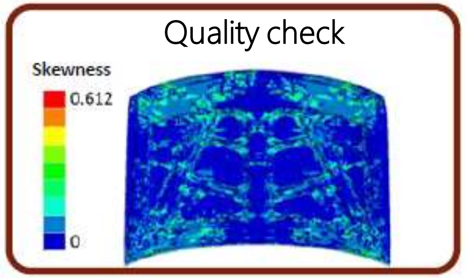


Honda Accord mesh
matching the
Chevrolet Silverado shape

Morphing onto the performances (parameter-based)



Honda Accord mesh
matching the
Chevrolet Silverado shape
and crashworthiness needs



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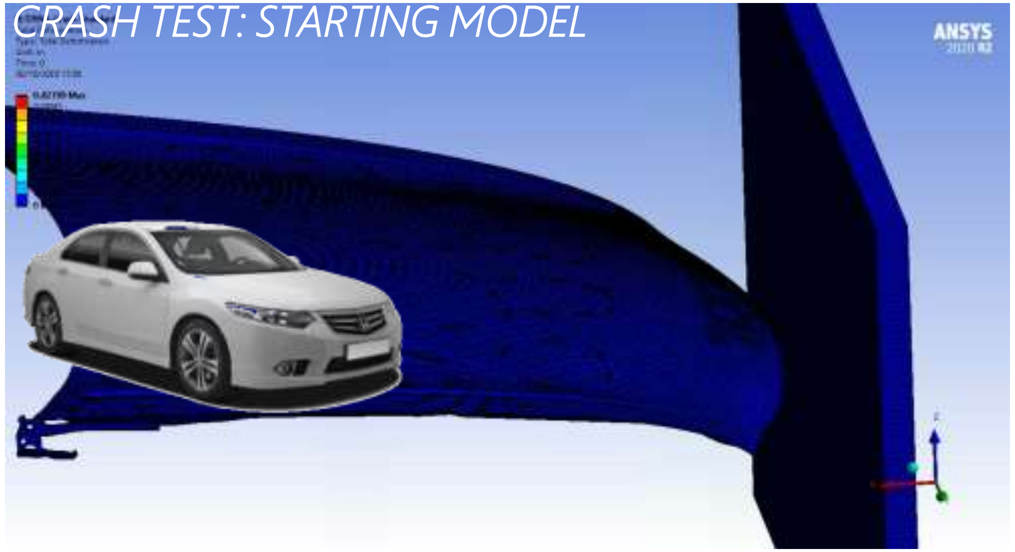
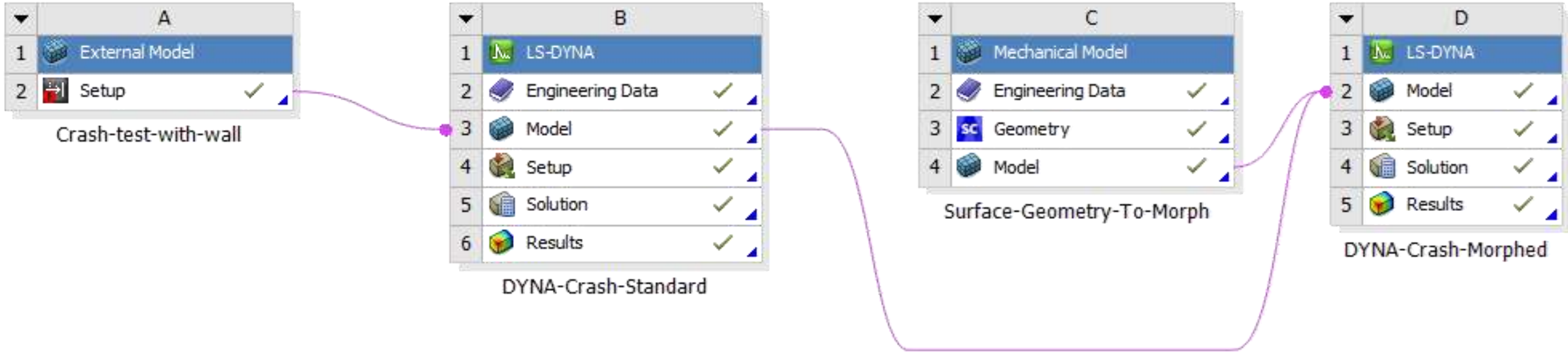
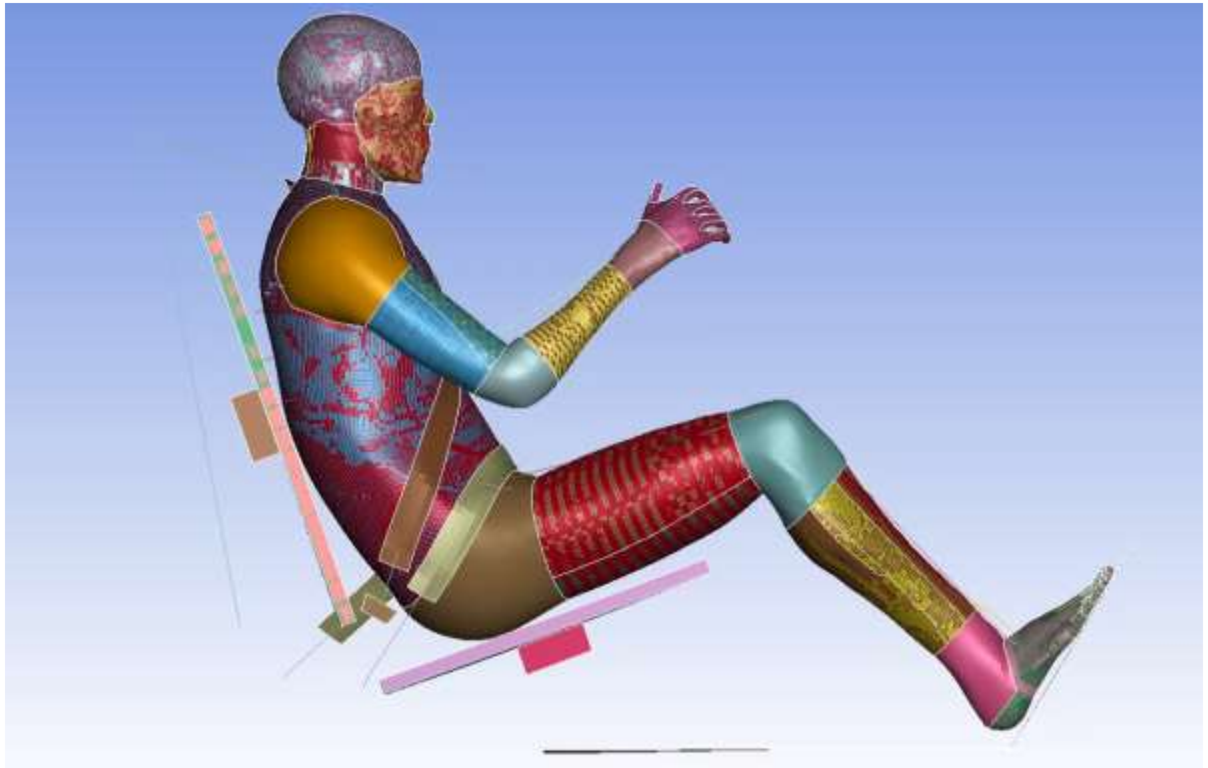
Reusing the LS-DYNA model of a different car





Parametric THUMS

- The morphing is performed on the THUMS Occupant AM50 model through an automated procedure
- Each edge of the THUMS is chosen as a set of source points which drive the overall mesh morphing



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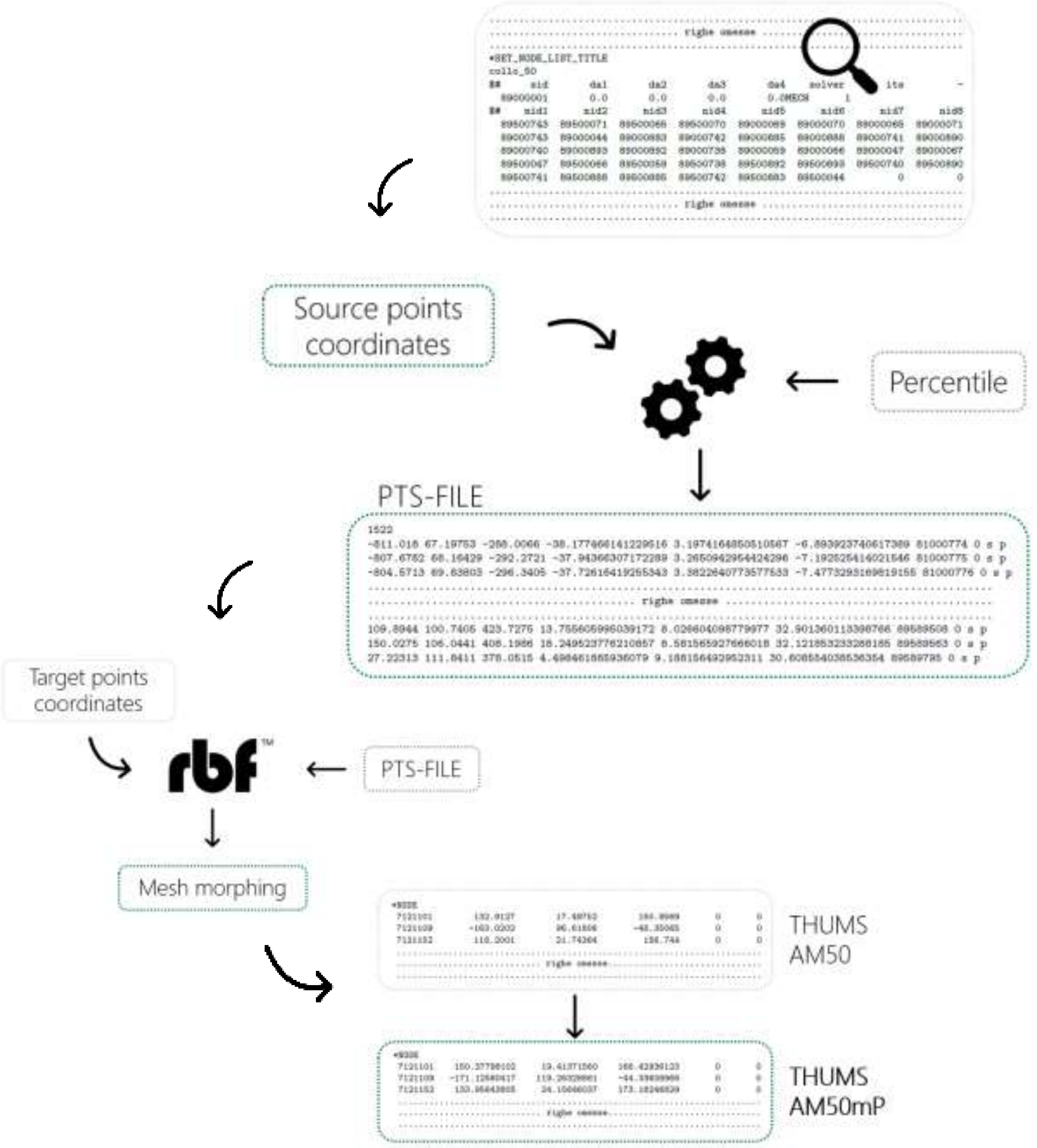
Parametric THUMS

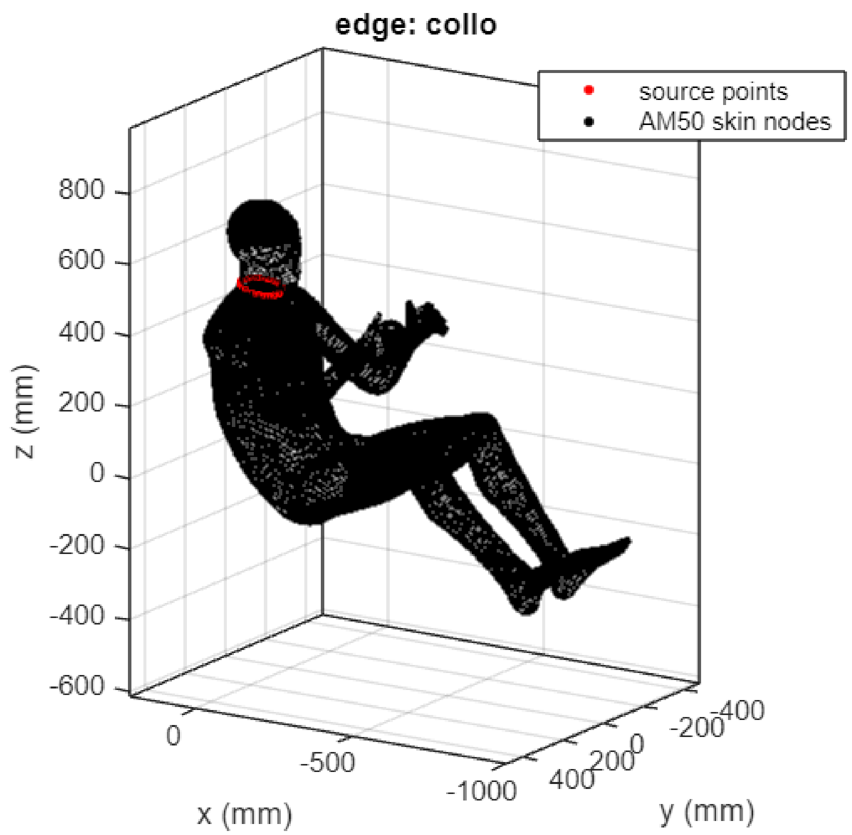
- The setup is performed in three steps:
  - Source points identification (LS PrePost)
  - Mesh Morphing (rbfCAE)
  - Morphing verification (Python script)



Parametric THUMS – Source Points

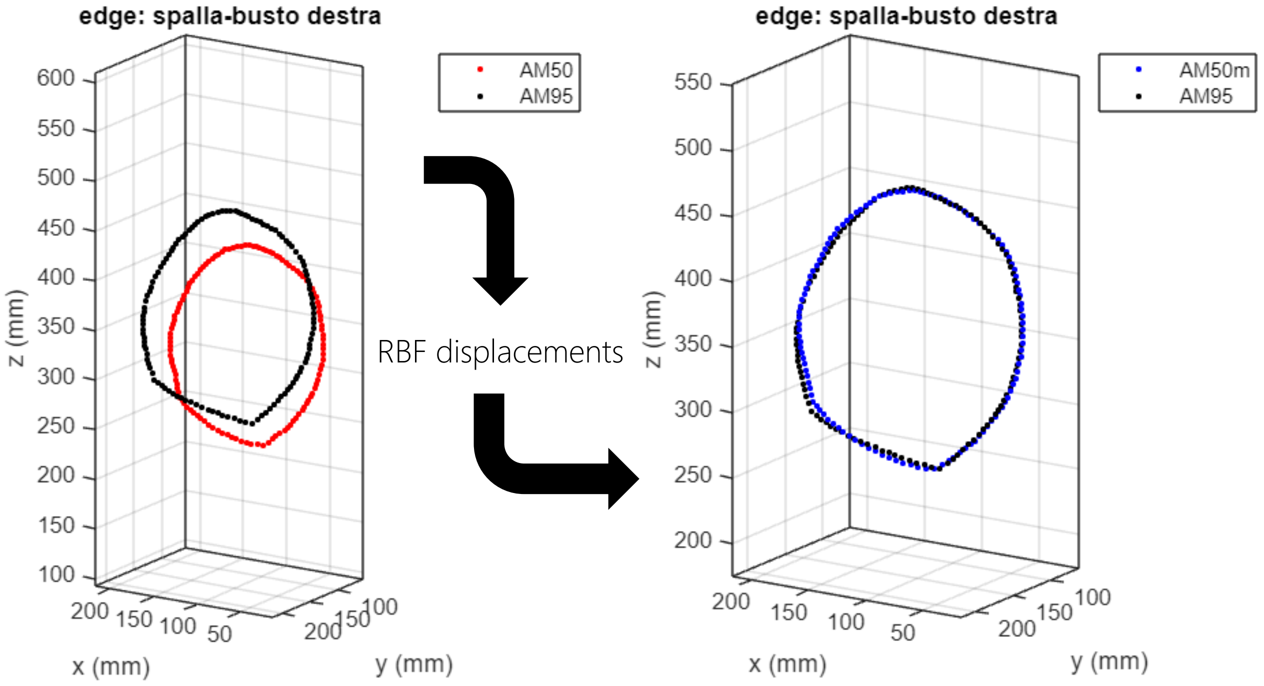
- Source points identification is performed in LS PrePost by exporting specific entities corresponding to the THUMS model edges on AM50 and AM95

```
*SET_NODE_LIST_TITLE
collo_50
$#     sid       da1       da2       da3       da4    solver       its         -
  89000001       0.0       0.0       0.0       0.0MECH       1
$#    nid1      nid2      nid3      nid4      nid5      nid6      nid7      nid8
  89500743  89500071  89500065  89500070  89000069  89000070  89000065  89000071
  89000743  89000044  89000883  89000742  89000885  89000888  89000741  89000890
  89000740  89000893  89000892  89000738  89000059  89000066  89000047  89000067
  89500047  89500066  89500059  89500738  89500892  89500893  89500740  89500890
  89500741  89500888  89500885  89500742  89500883  89500044         0         0
```



Parametric THUMS – Mesh Morphing

- RBF displacements are calculated for all the nodes on selected entities
- Based on all RBF displacements, the PTS-file is generated to take AM50 nodes to AM95 position
- This step is needed to apply displacement to the AM50 model keeping it iso-topological



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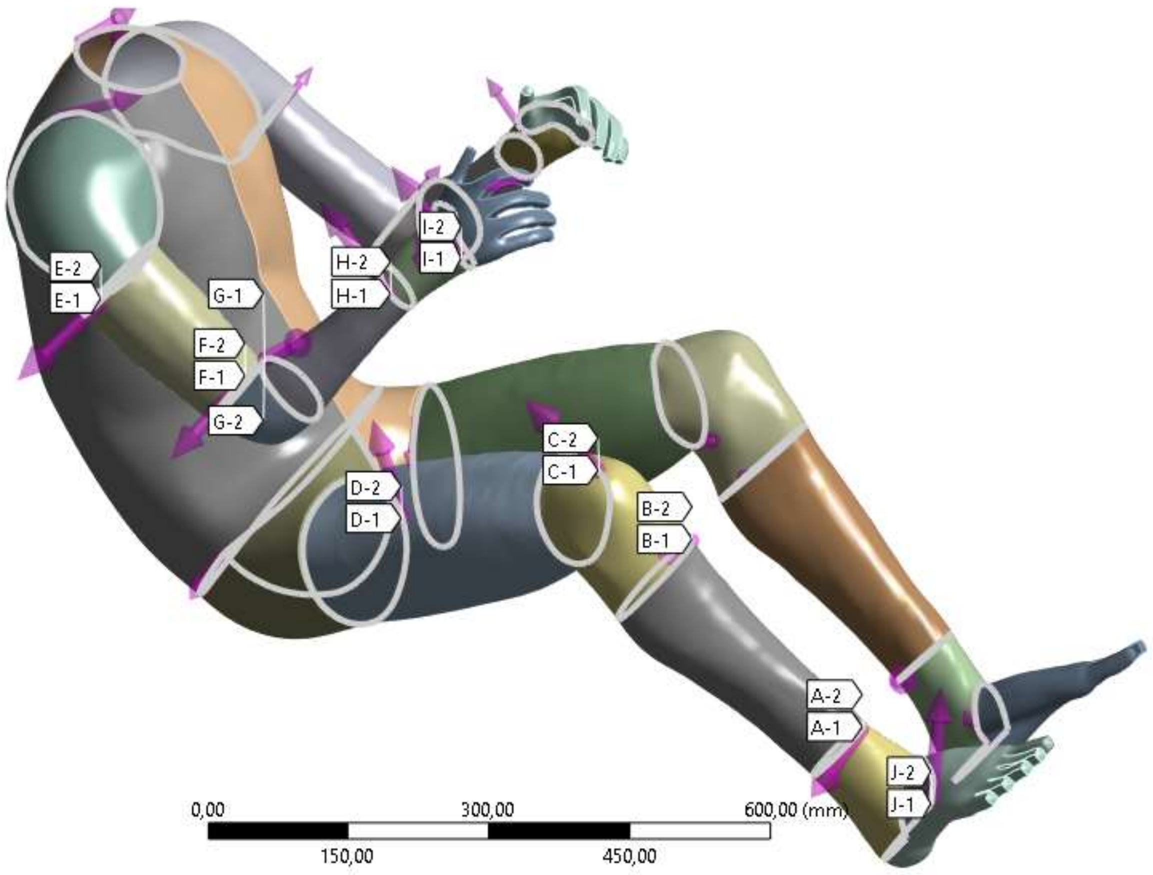
Parametric THUMS – Morphed model

- This setup has been replicated for each region (except from the head) optaining a morphed working case in **less than 10 seconds**
- THUMS model can be adapted to both intermediate and smaller shapes through a scale factor



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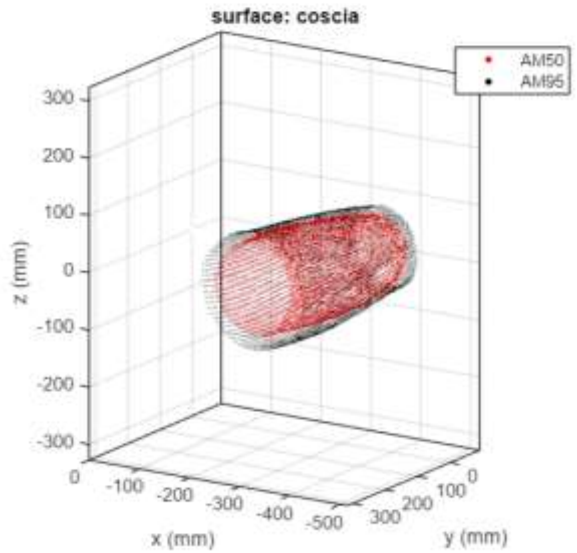
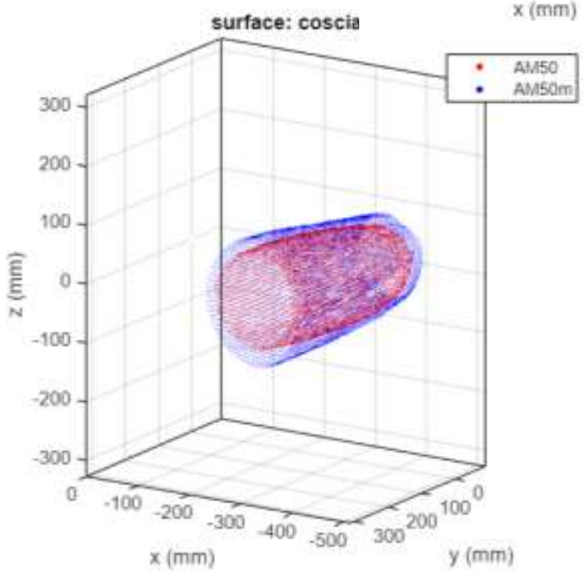
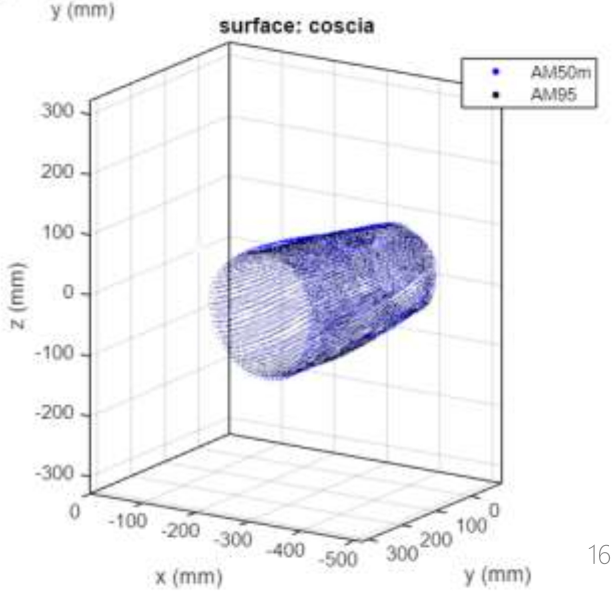
Parametric THUMS – Morphing verification

- To validate the mesh morphing a minimum pinball mean radius has been defined
- A comparison between original and morphed nodes is shown in these images







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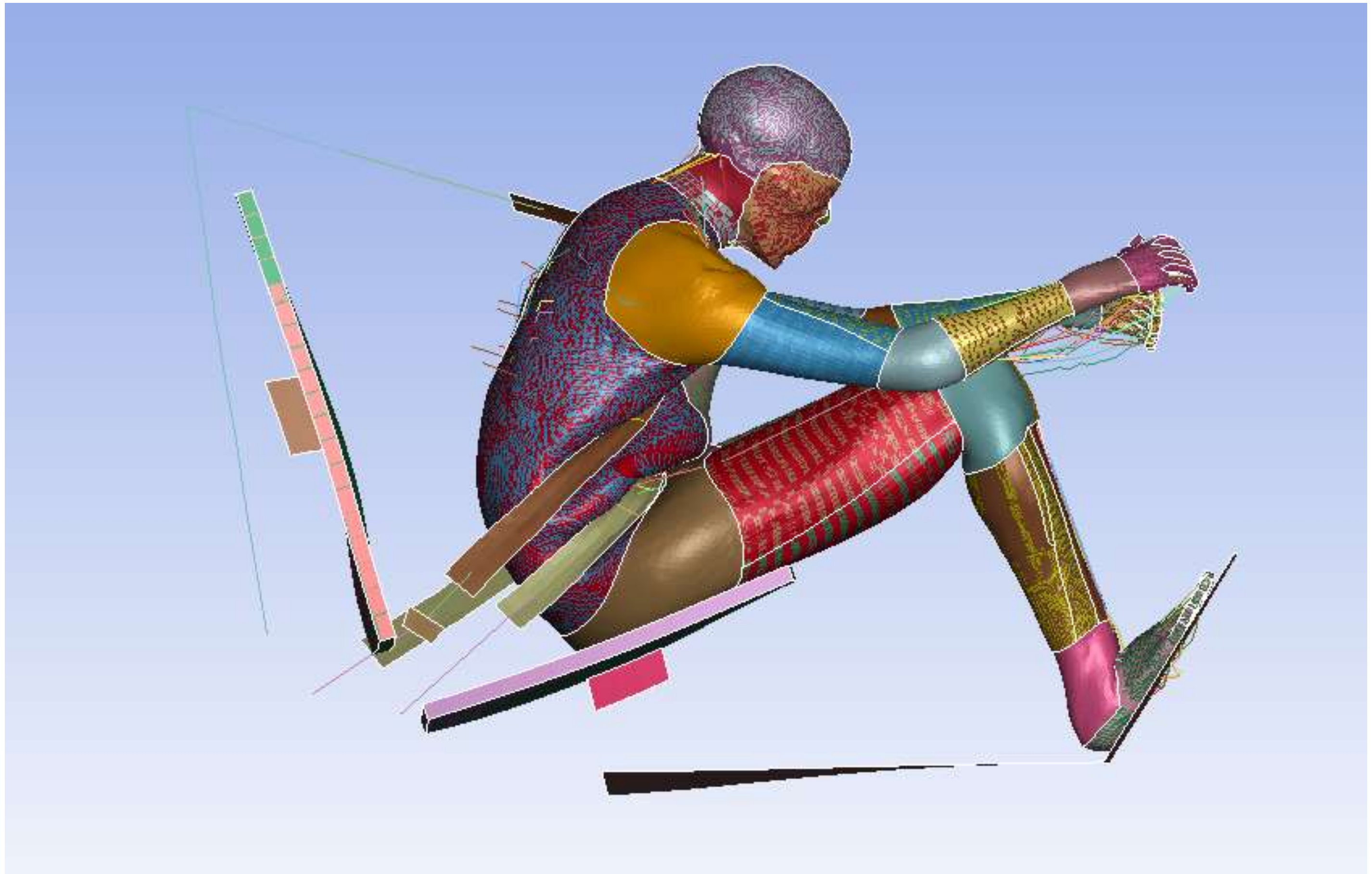
Parametric THUMS – Sled test

- The parametric THUMS sled test validation set has been analyzed
- Skin and bones drive morphing
- The morphed THUMS has been verified also for intermediate and smaller shapes



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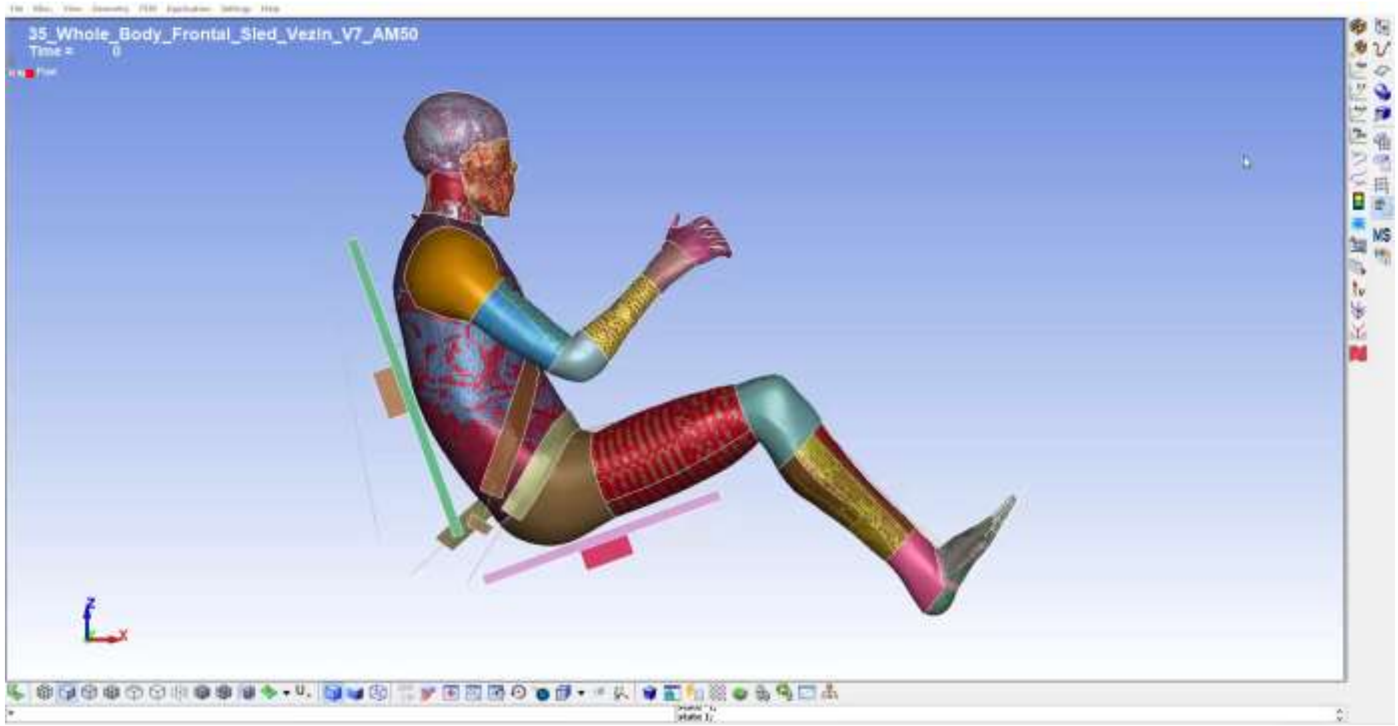
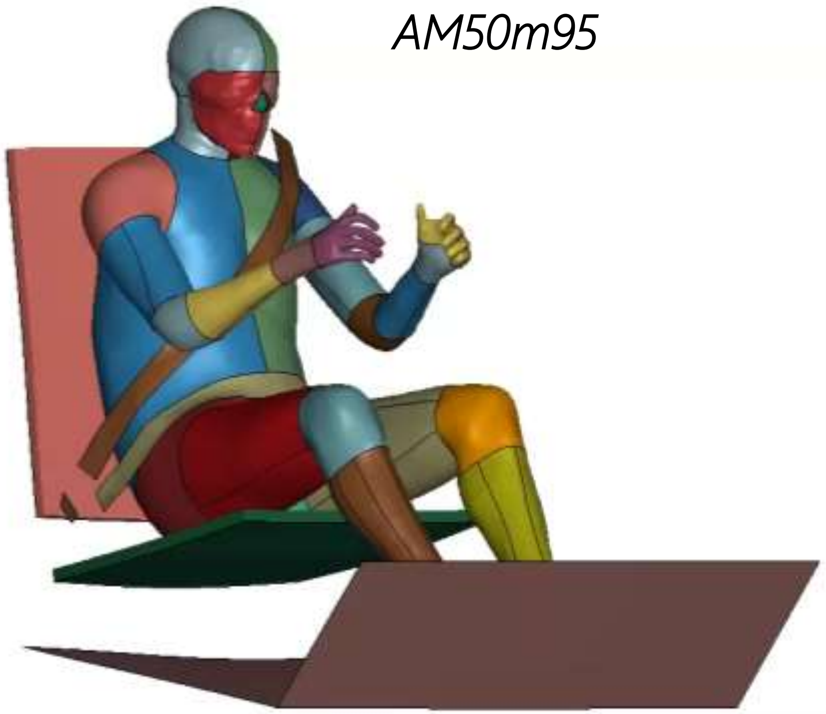
Parametric THUMS – Sled test





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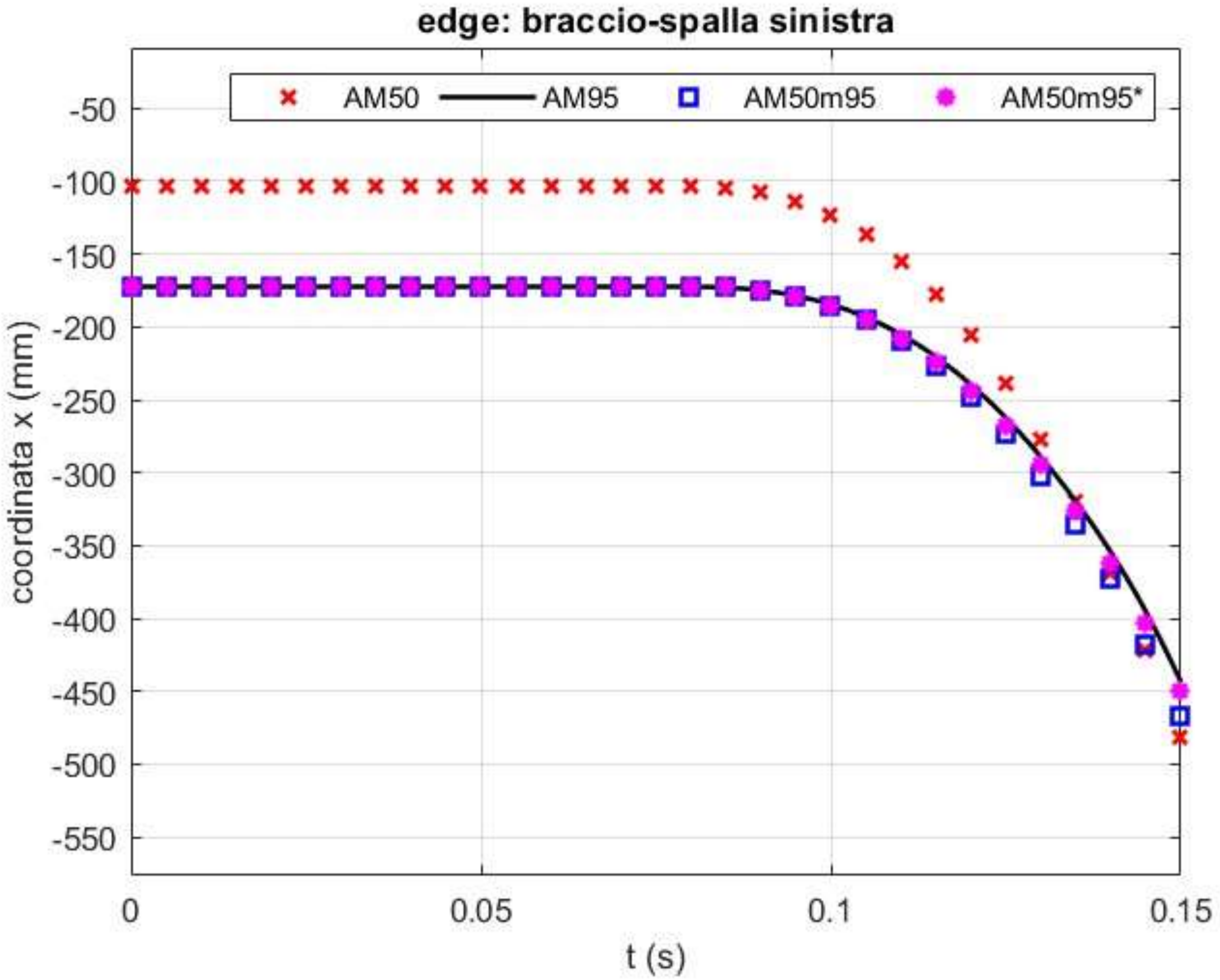
Parametric THUMS – Sled test

- Displacements have been evaluated between different THUMS model
- The parametric THUMS morphed model (AM50m95) shows a strong fit with the original AM95 curve



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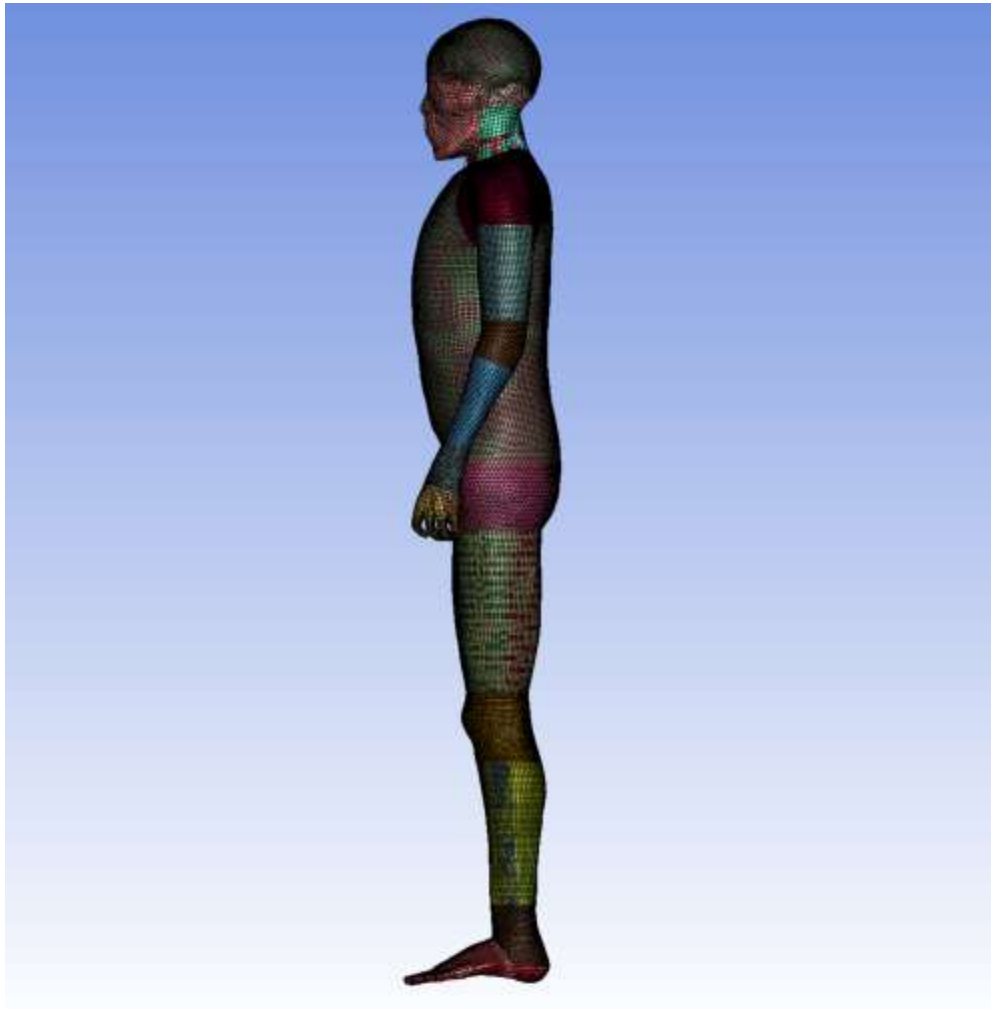
Parametric THUMS – Positioning

- A procedure for THUMS positioning has been implemented on the AM50 pedestrian model
- The setup is performed in three steps:
  - Skin model positioning (Blender)
  - RBF displacement evaulation (Python script)
  - Mesh Morphing (rbfCAE)



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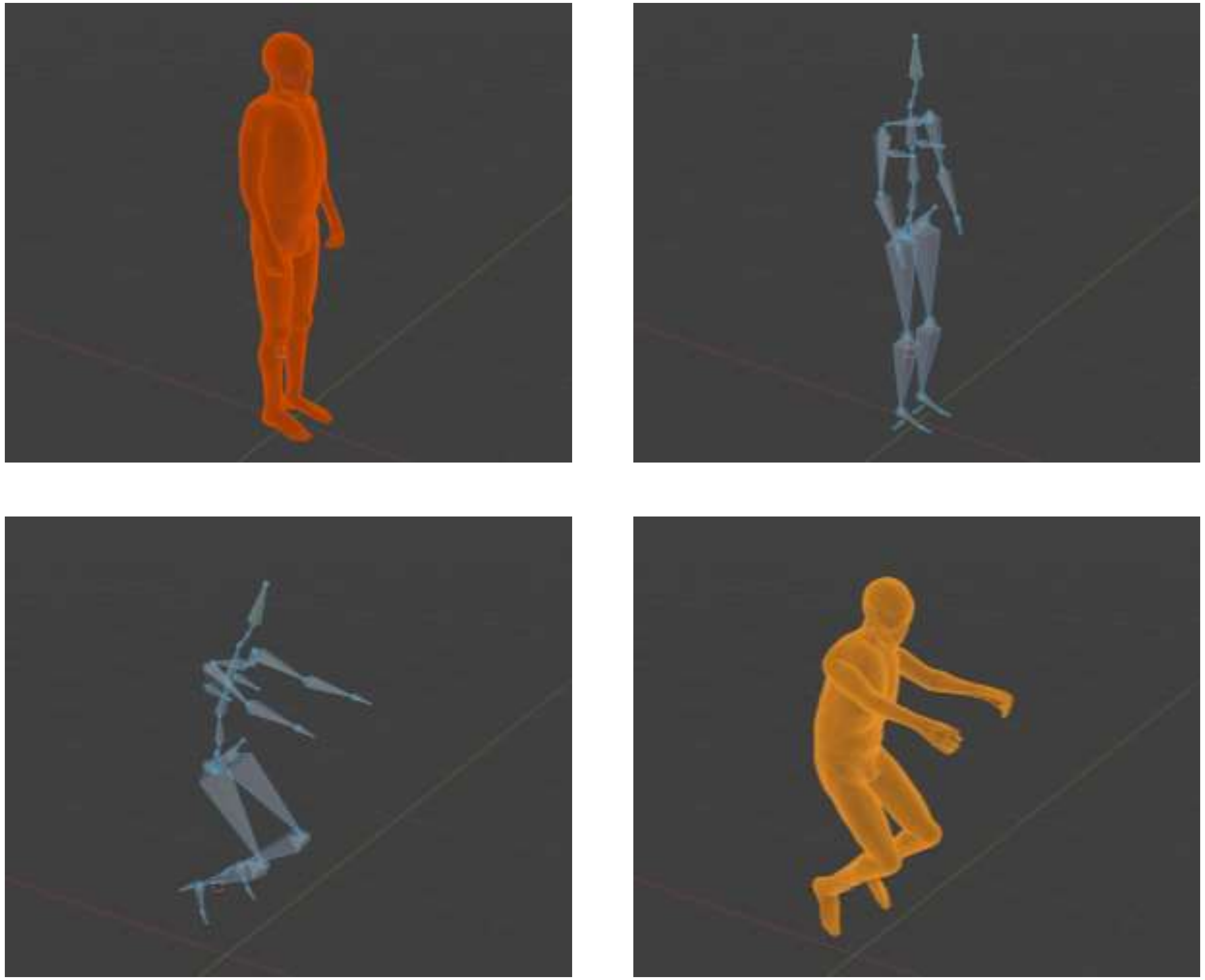
Parametric THUMS – Positioning

- The THUMS skin mesh has been extracted and imported as .stl file in the Blender software
- A parametric rig has been created through the rigify tool associating the mesh and the rig
- The articulated mesh is exported as .ply file



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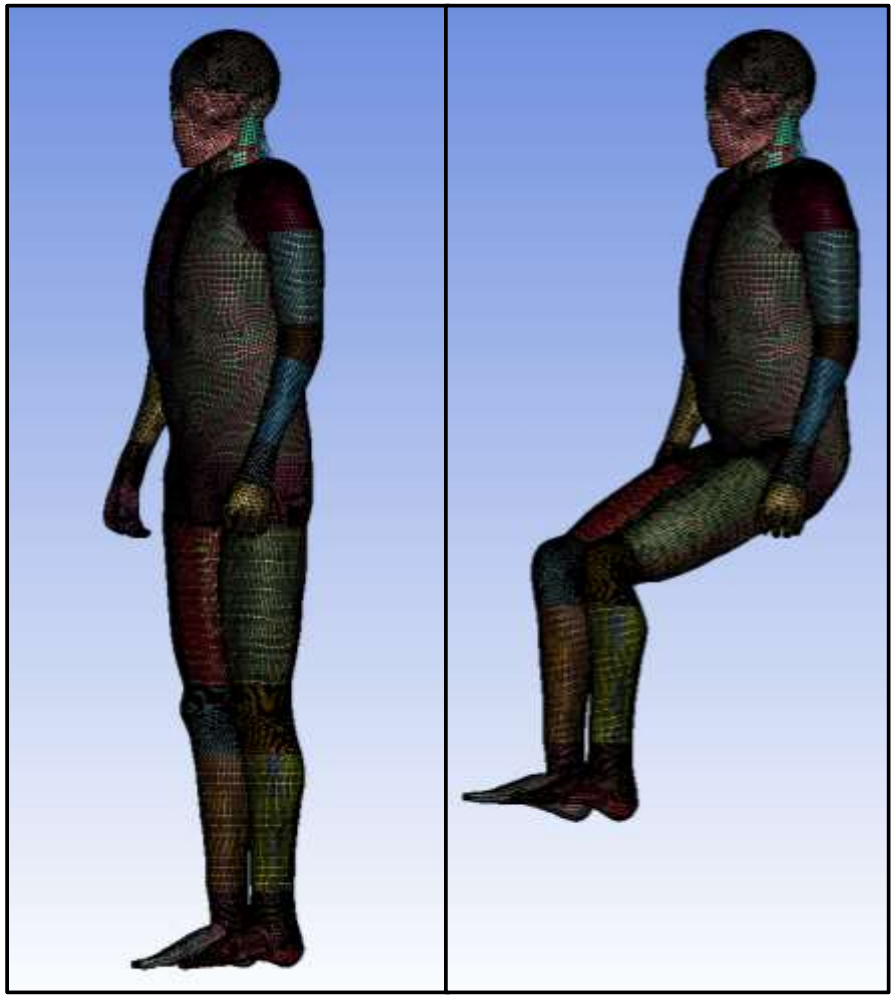
Parametric THUMS – Positioning

- A custom script reads the new position and an RBF displacements file is created
- The RBF displacements are applied to the original AM50 Pedestrian model to be morphed into the final position
- Morphing calculation is performed in about **45 seconds** through rbfCAE
- Currently implementing a verification method for mesh quality



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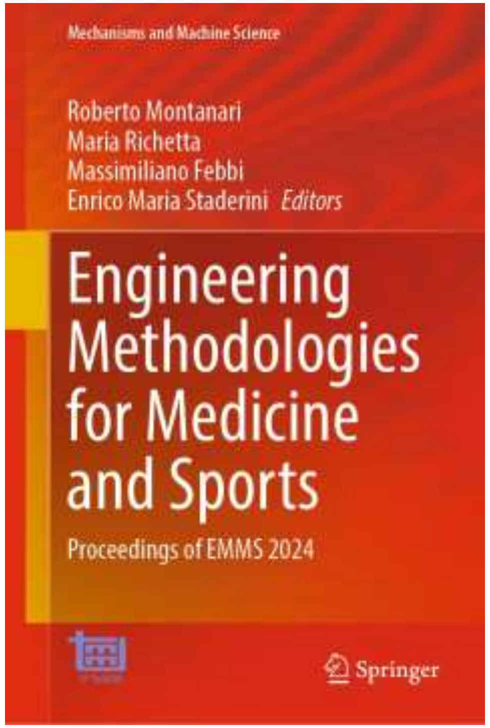
Parametric THUMS presentations at aCAE Grand Challenge 2024 and EMMS 2024

https://www.carhs.de/en/grand-challenge-proceedings.html



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