Integrated Multi-Physics Optimization of Automotive Road Wheels Using Advanced Mesh Morphing

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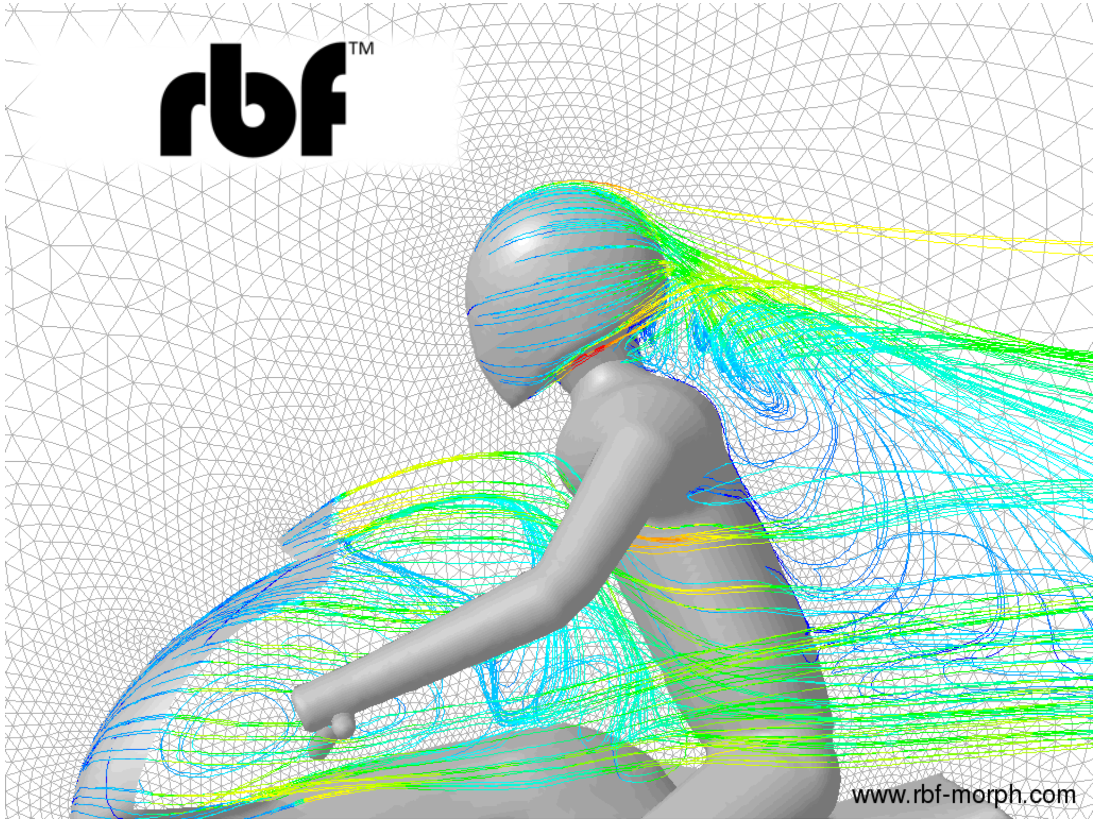
Outline

- An overview about the rbfCAE platform
- Typical usage scenarios and applications
- Study Objective
- Case Study: 18'' Wheel
- Integrated Methodology
- Case Setup
- Optimization Results
- Conclusions and Future Work

radial **b**asis **f**unctions morphing of **CAE** models - rbfCAE

- Geometric control by radial basis functions CAE morphing
  - Surface shape changes
  - Volume mesh adaption
- A new shape of the CAE model ready to run
  - for structures in the FEA solver
  - for flows in the CFD solver



radial basis functions Excellence

- We offer best in class Radial Basis Functions (RBF) to drive CAE morphing from a list of source points and their displacements
- RBF are recognized to be one of the **best mathematical tool** for mesh morphing

$$\begin{cases} s_x(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^x \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) + \beta_1^x + \beta_2^x x + \beta_3^x y + \beta_4^x z \\ s_y(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^y \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) + \beta_1^y + \beta_2^y x + \beta_3^y y + \beta_4^y z \\ s_z(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^z \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) + \beta_1^z + \beta_2^z x + \beta_3^z y + \beta_4^z z \end{cases}$$

EU-funded research projects

RBF4AERO

FORTISSIMO

RIBES

CloudiFacturing

EUROfusion

spinner
next generation spine experts

MEDITATE

ff4EuroHPC

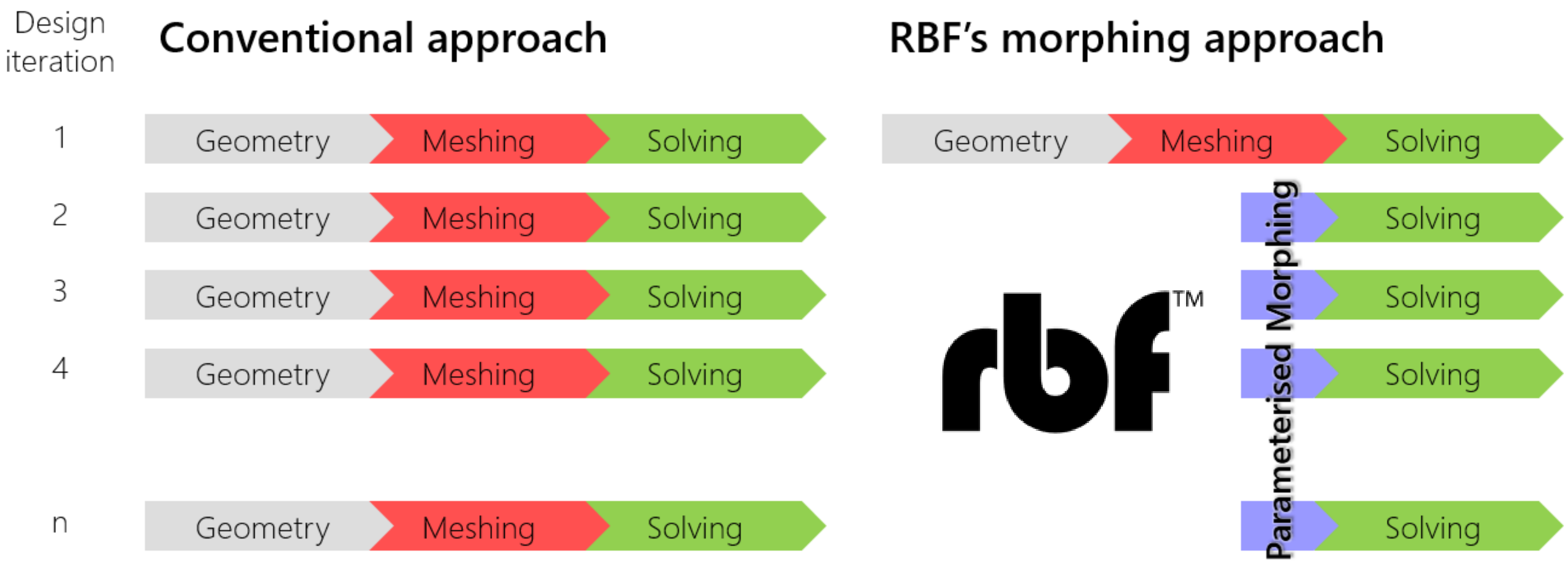
rbfCAE solution benefits

www.rbf-morph.com

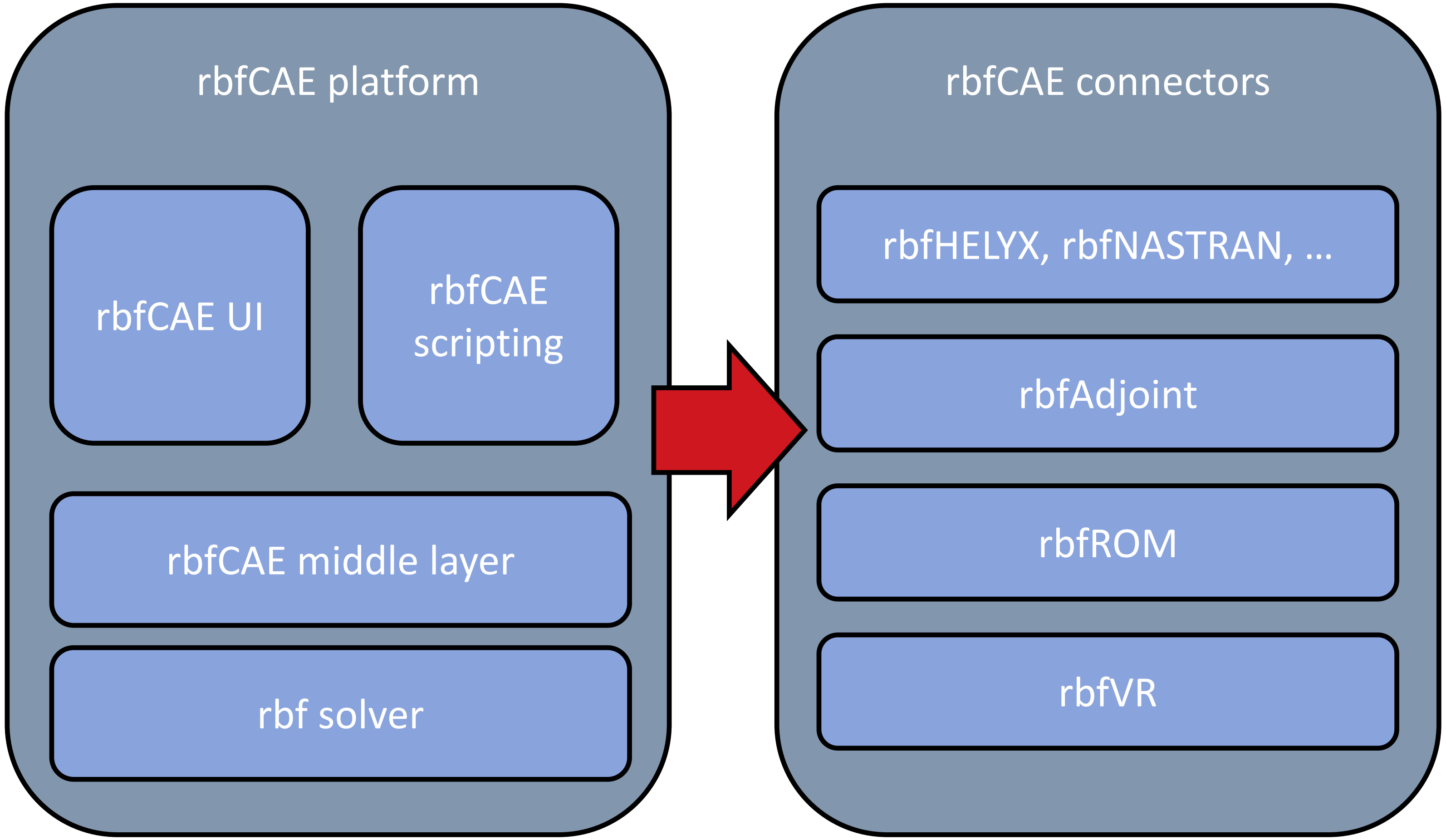
- No re-meshing
- Can handle any kind of mesh
- Can be integrated in the CAE solver (FEM/CFD/FSI)
- Highly parallelizable
- Robust process
- The same mesh topology is preserved (adjoint/ROM)
- CAD morphing (iso-brep)

rbfCAE parametric models

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

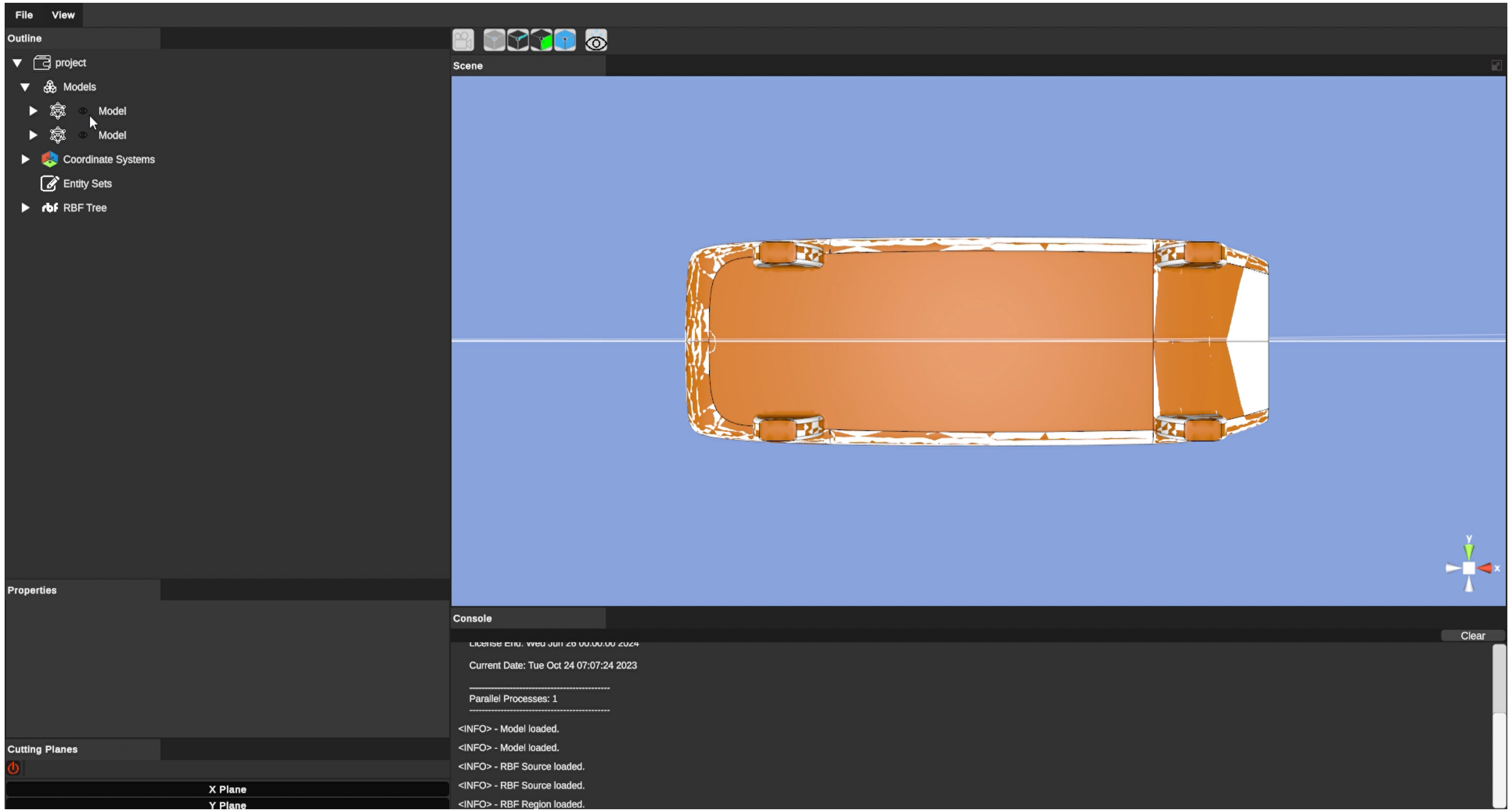


rbfCAE solution



- Released in 2024
- Read in **STL, STEP**
- **Unity - OpenCascade**
- Solver independent process that supports **many mesh formats**
- **Scriptable** via Python

rbfCAE UI



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Main uses of rbfCAE

Usage	FEA	CFD	Optimizer	AI
Automated and quick variable design space exploration	✓	✓		
Optimization (Single physics or multi-physics) Shape optimization for stress reduction, mass reduction, fluid-structure interaction	✓	✓	✓	
Digital twin development (static ROMs)	✓	✓	✓	✓
Lifing applications simulate defects such as corrosion pits, spalling of material, erosion, chips, etc.	✓	✓		
Examine the effects of non-conformance and manufacturing variability	✓	✓		
Robust Design	✓	✓	✓	

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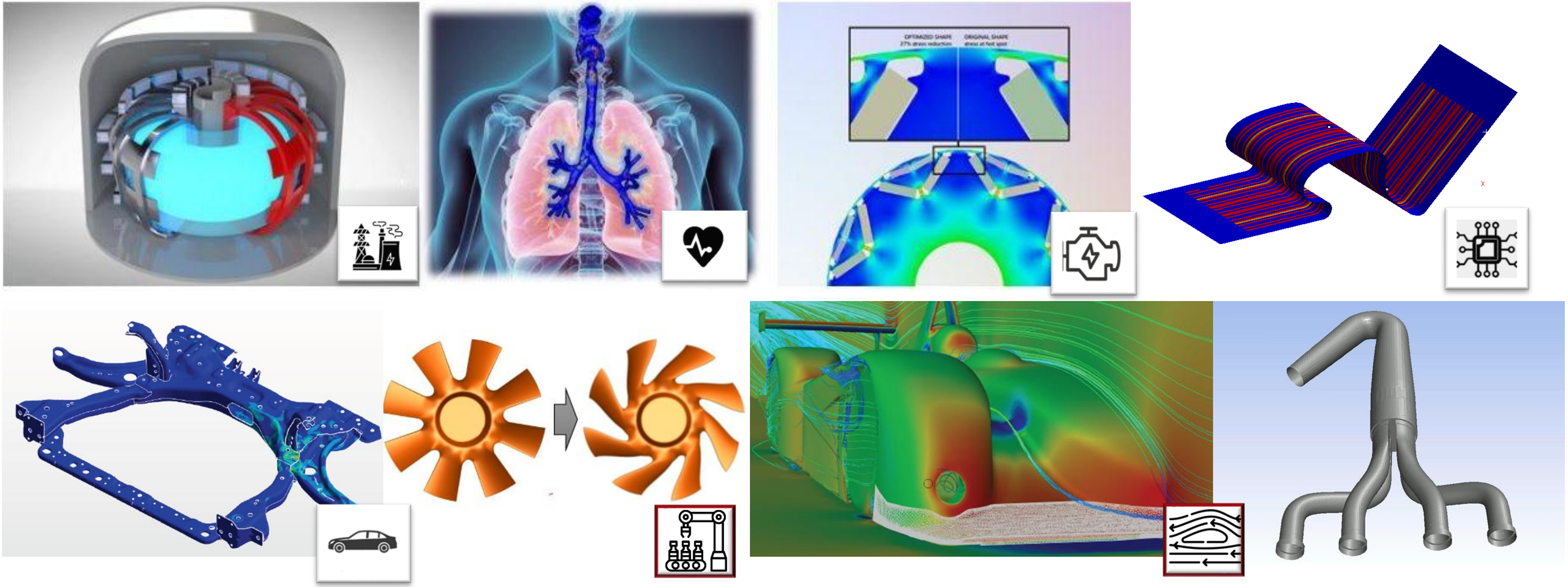
Served industries

100+
Global Customers



Study Objective

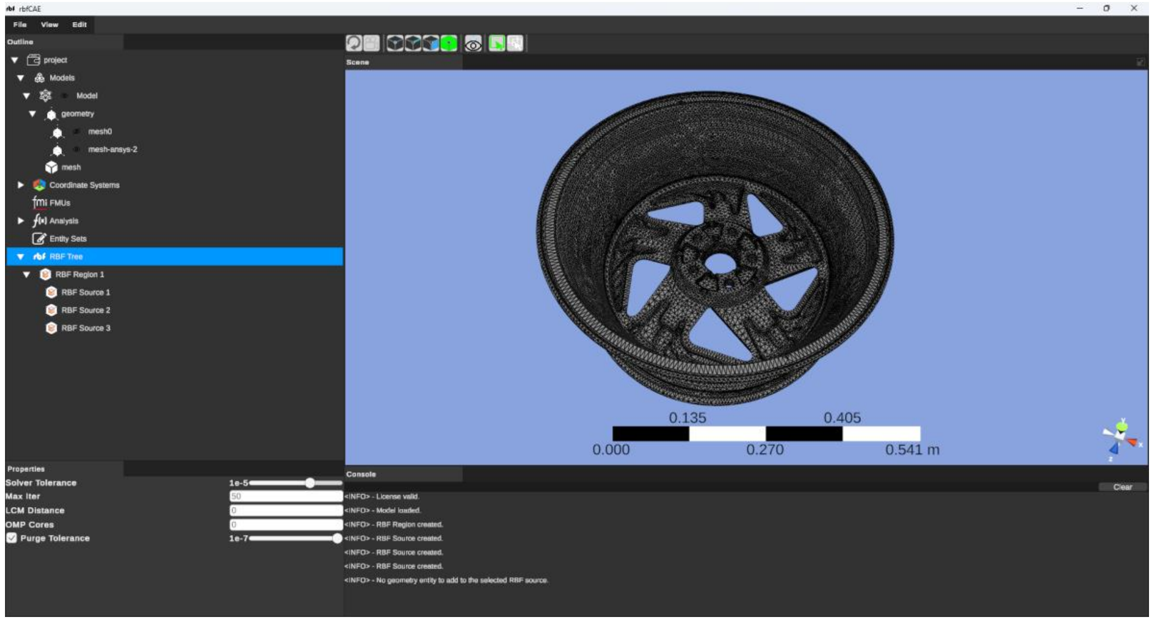
- Three competing requirements:
  – Styling
  – Structural performance
  – Aerodynamic efficiency
- Multi-physics and simulation-driven design
- Specific focus on electric vehicles

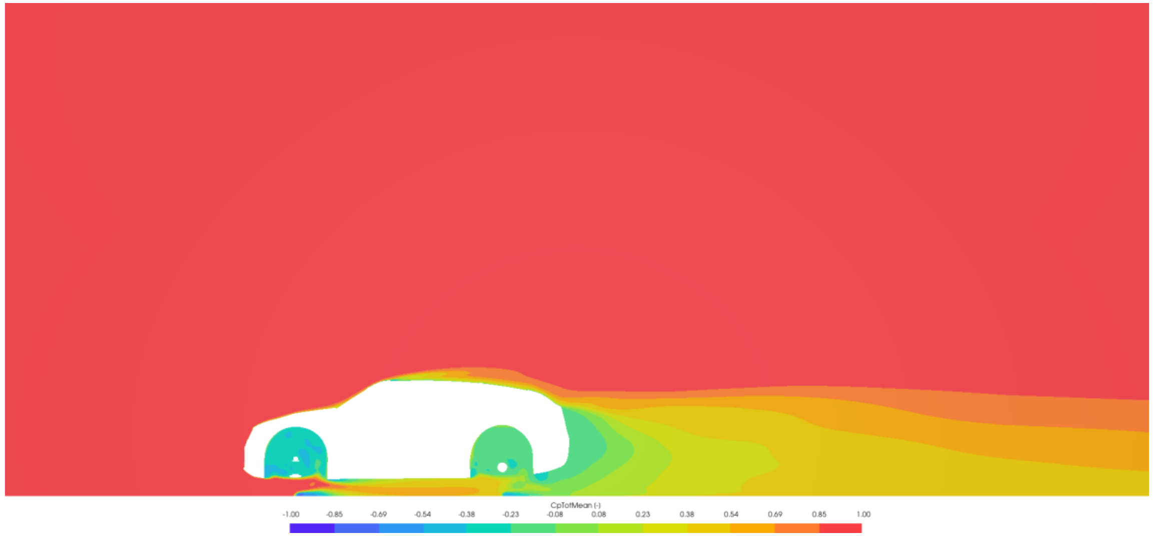
Case Study: 18" Wheel

- Parametric and BGM-based mesh morphing to optimize wheel performance
- Structural optimization to achieve mass reduction
- Aerodynamic evaluation with wheel mounted on AeroSUV model

Integrated Methodology

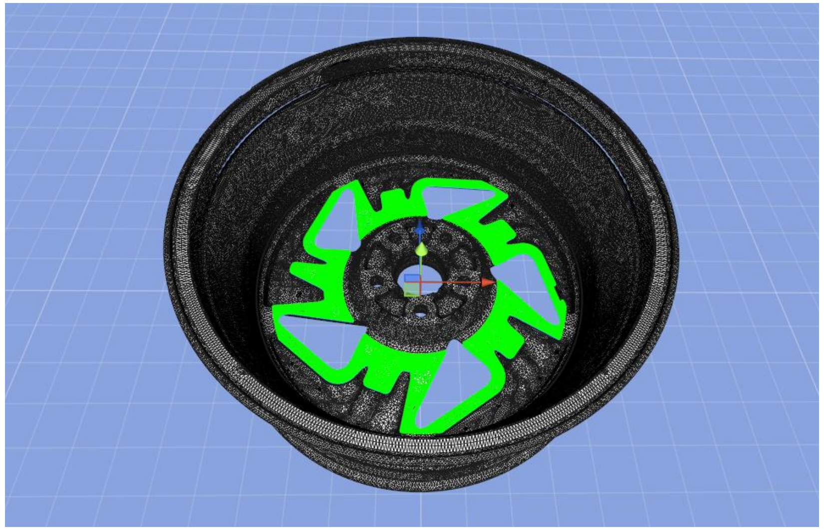
- Full CAE workflow
  - Mesh morphing (rbfCAE)
  - FEM (NX Nastran)
  - CFD (HELYX)
- rbfCAE mesh morphing:
  no full remeshing needed
- Automatic mesh updates across FEM and CFD solvers via rbfCAE platform

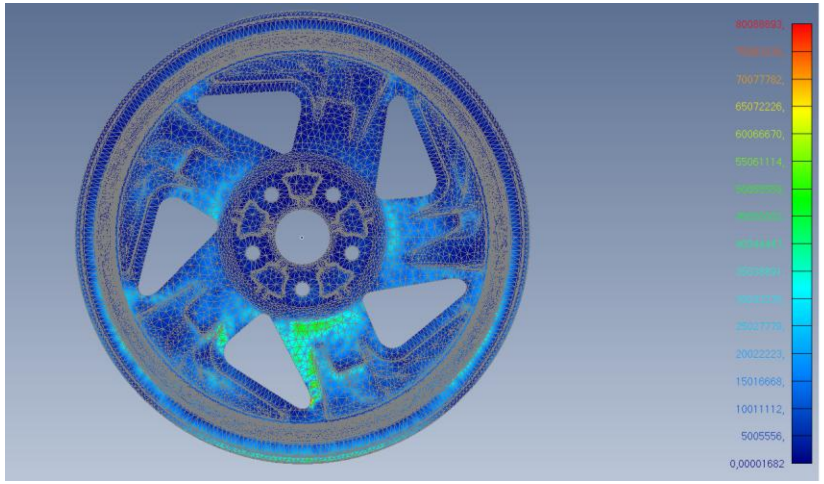




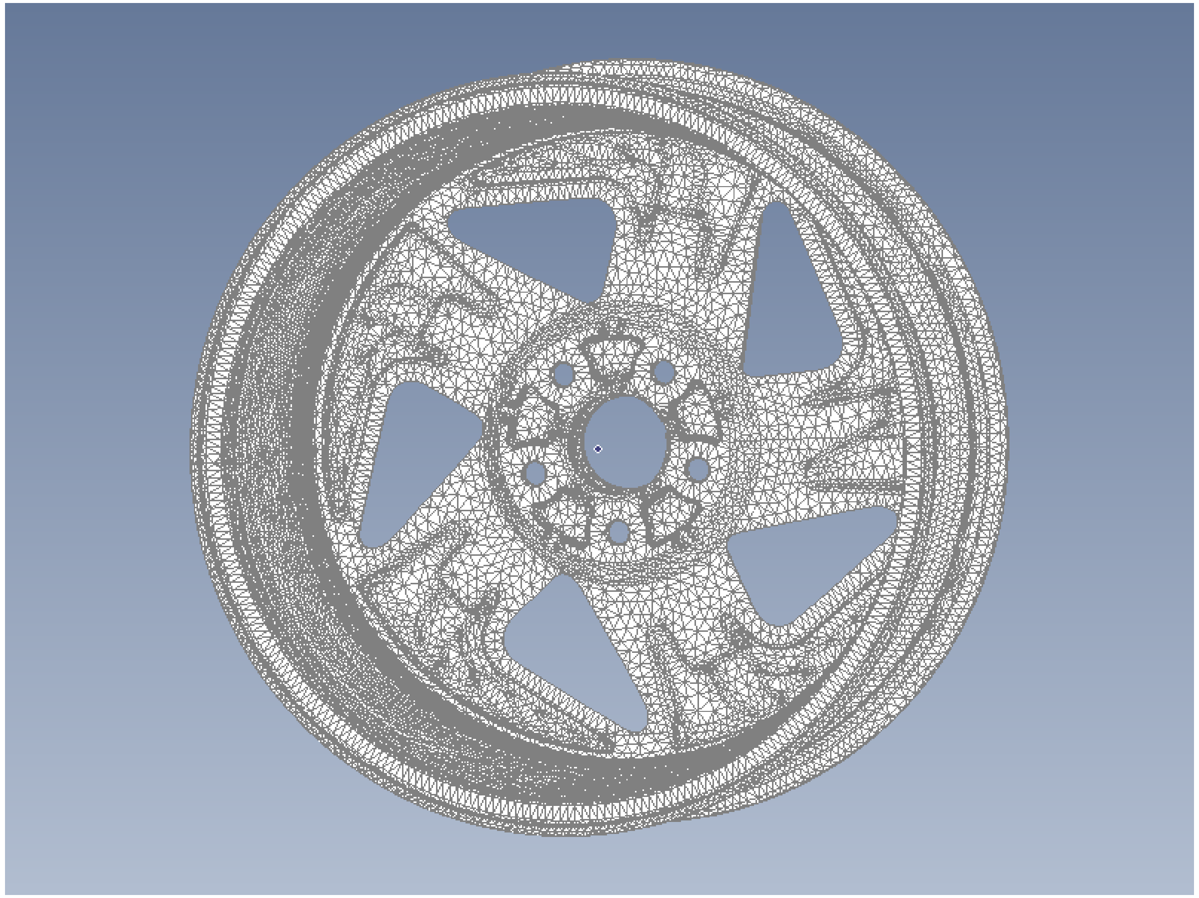
Parametric and BGM-based Morphing

- Parametric Morphing: controlled deformations via predefined parameters
  - Surface offsets applied internally
  - External faces preserved (styling constraint)
  - Minimum thickness constraint: 3.5 mm
- BGM Morphing: shape evolution driven by Von Mises stress distribution
  - Target stress: 72 MPa
  - Maximum local thickness reduction: 2 mm
  - Adaptive mass reduction in low-stress areas





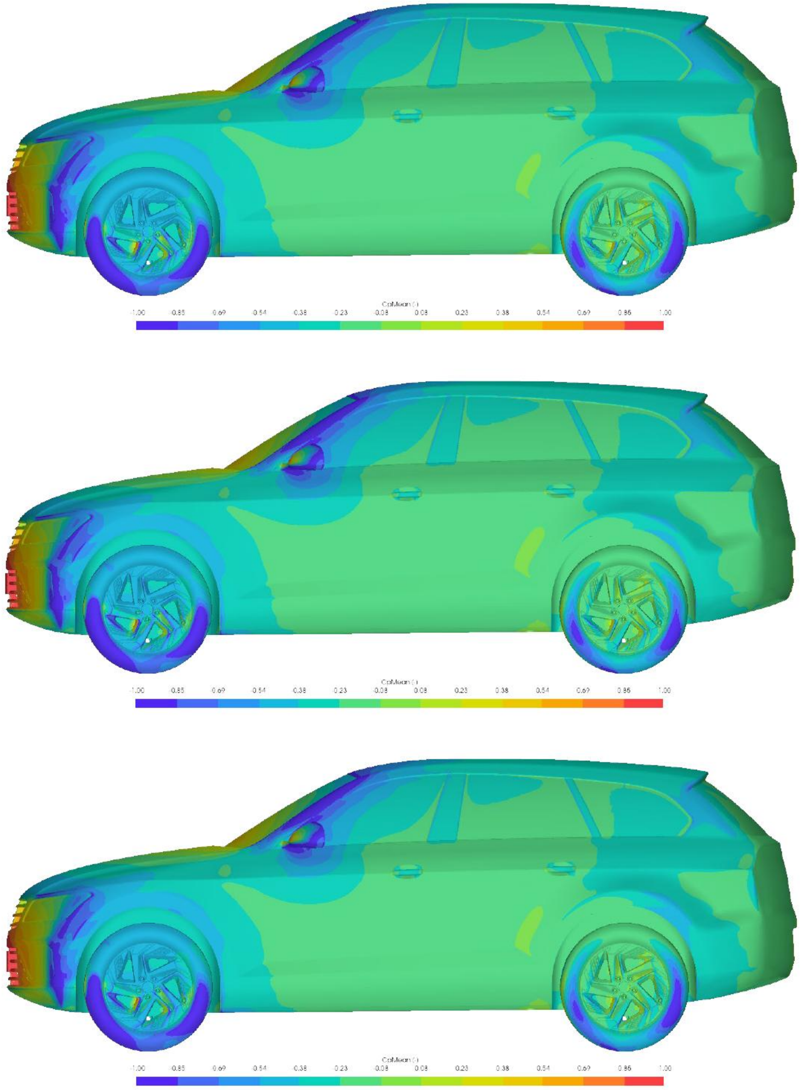
FEA Setup



- Solver: NX Nastran
- Material: AlSi7Mg0.3 aluminum alloy
- Mesh: ~260,000 second-order tetrahedral elements
- Analysis type: Static Structural
- Load cases: Impact, fatigue
- Peak stress (baseline): ~78 MPa (Yield Strength: 190 MPa)

CFD Setup

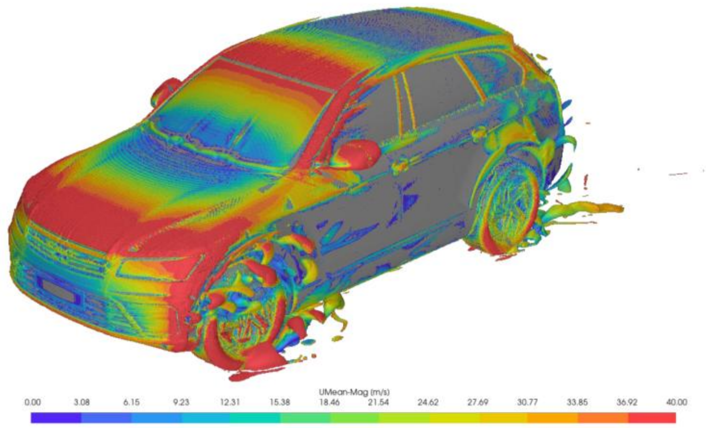
- Solver: HELYX
- Mesh size: ~60 million cells
- Flow modeling: Steady-state RANS
- Turbulence model: k-ω SST
- Wheel modelling: MRF (Multiple Reference Frame)
- Speed: 140 km/h
- Drag coefficient (baseline): 0.302

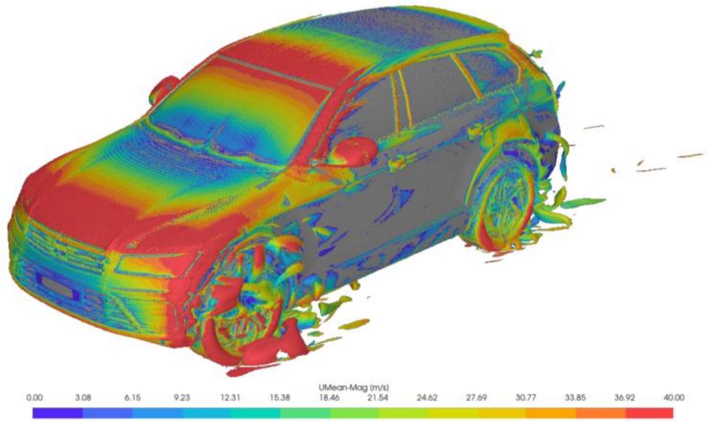


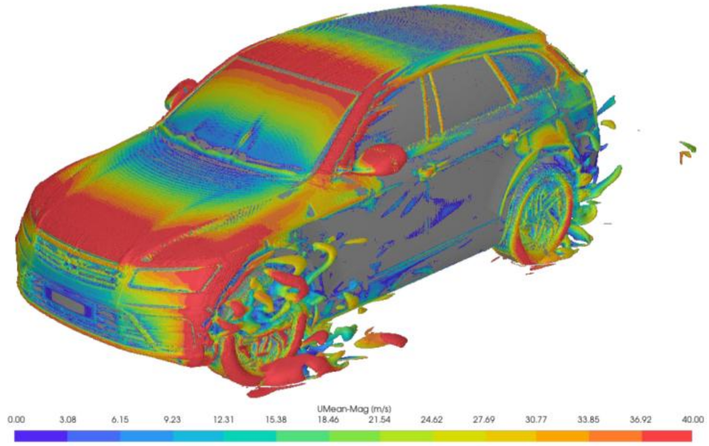
Results

- Weight reduction per wheel: -0.4 kg
- Stress < Yield strength
- Slight Cd increase (0.302 ➔ 0.304/0.305)
- Rear downforce improved
- Overall vehicle efficiency enhanced

Quantity	***Baseline***	***Parametric Morphing***	***BGM Morphing***
Mass [kg]	14.1	13.7	13.7
Von-Mises Stress [MPa]	78.1	81.3	75.9
Drag Coefficient (Cd)	0.302	0.304	0.305
Lift Coefficient (Cl)	-0.013	-0.025	-0.021

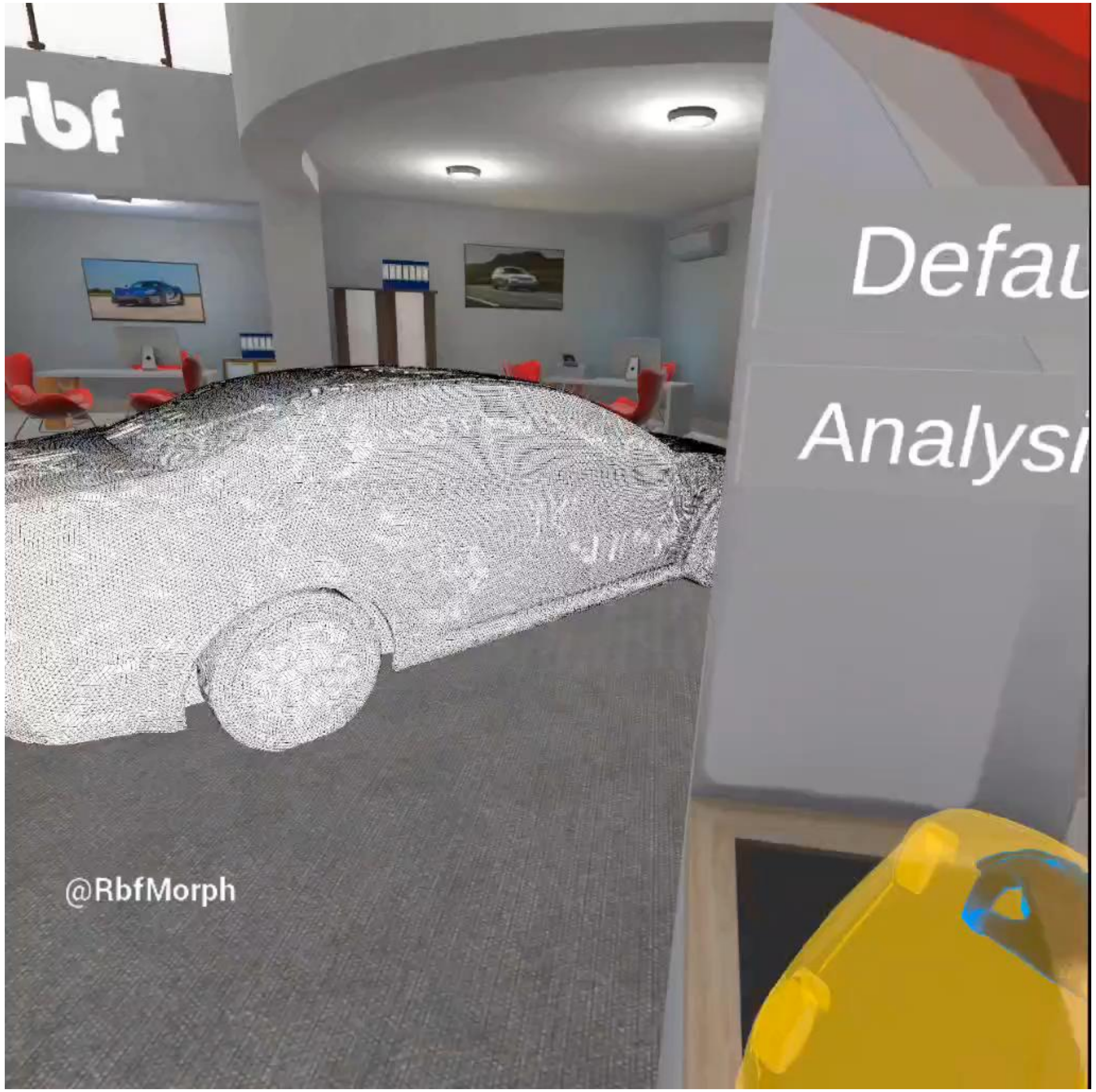






Conclusions and Future Work

- Conclusions:
  - Multi-physics optimization of wheels was successfully demonstrated
  - rbfCAE enables fast, high-fidelity shape updates across FEM and CFD
  - Both parametric and BGM morphing strategies reduced mass and preserved performance
  - Integrated workflow improved design efficiency and flexibility
- Future Work:
  - Integration of AI and ROMs to enable real-time design exploration
  - Extension to full vehicle-level optimization (e.g., wheel + flow + suspension)
  - Enhanced user experience with rbfVR for immersive design review



Thank you!

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