More than human in the loop: Next generation computational workflows for engineering design

Matthias Möller

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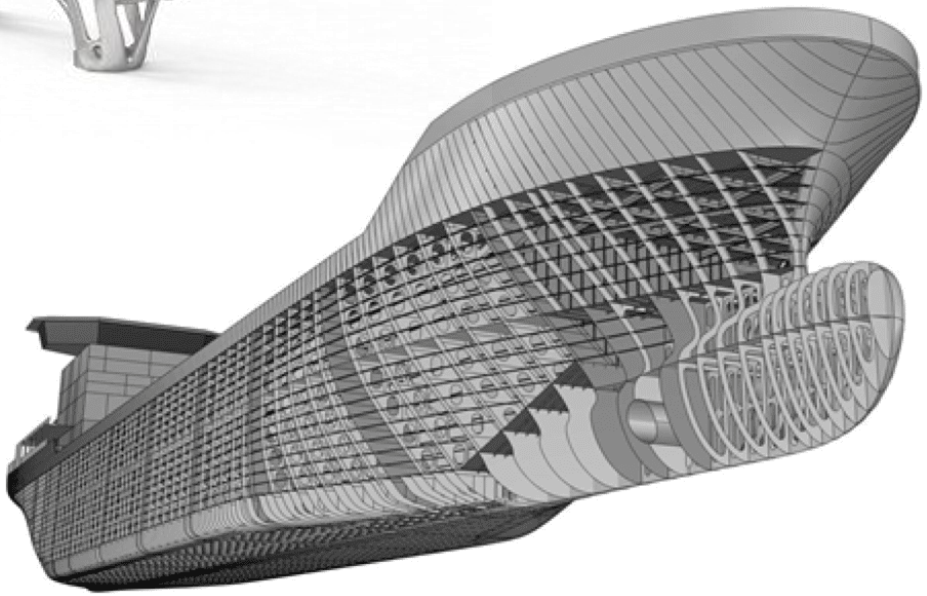
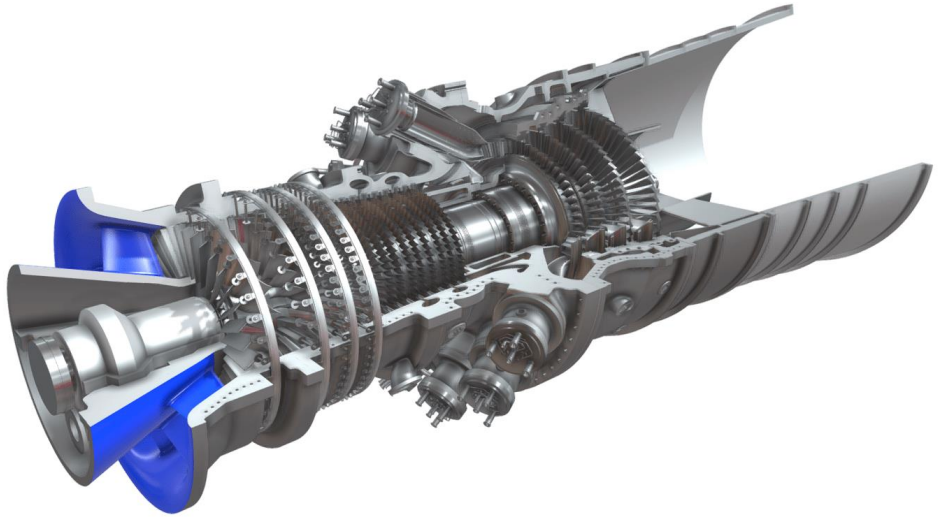
TU Delft

V0.2

Engineering designs



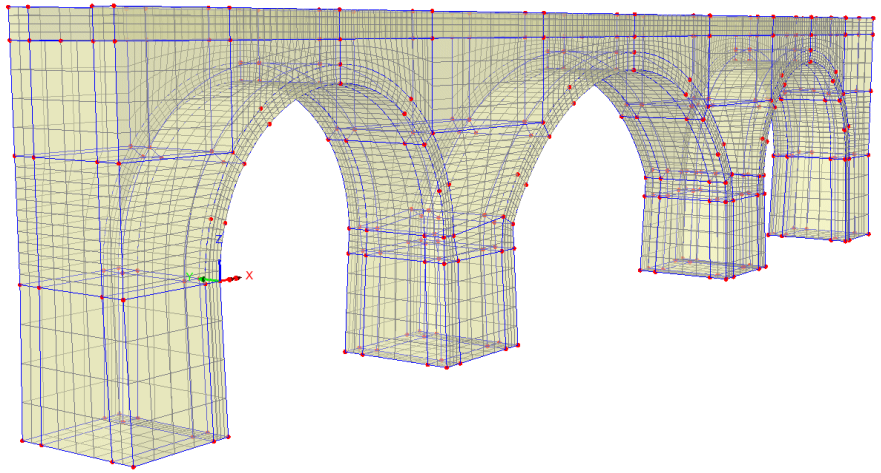


Engineering design workflows

- Design creation
- Performance analysis
- Design optimization
- Maintenance, overhaul & repair
- Digital twin technologies

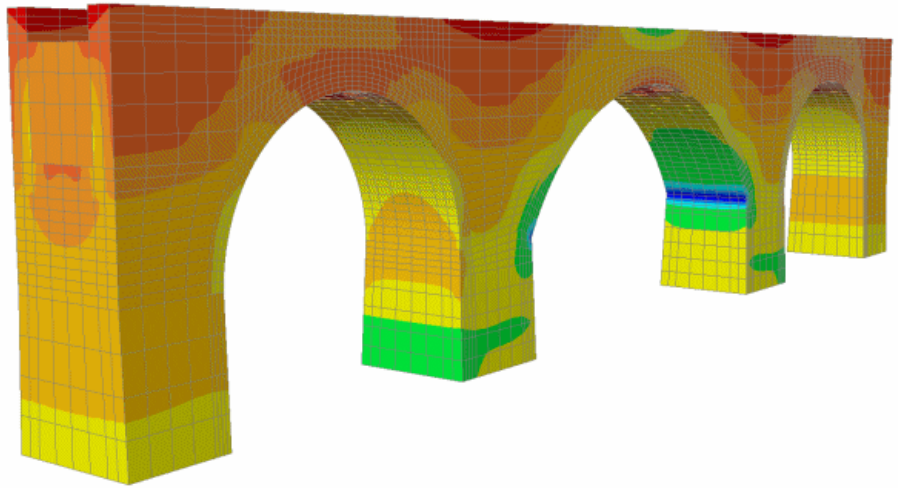
Engineering design workflows

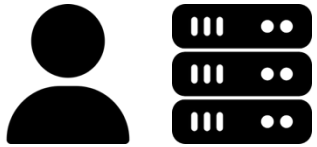
Computer-aided design (CAD)



interactive

Computer-aided engineering (CAE)

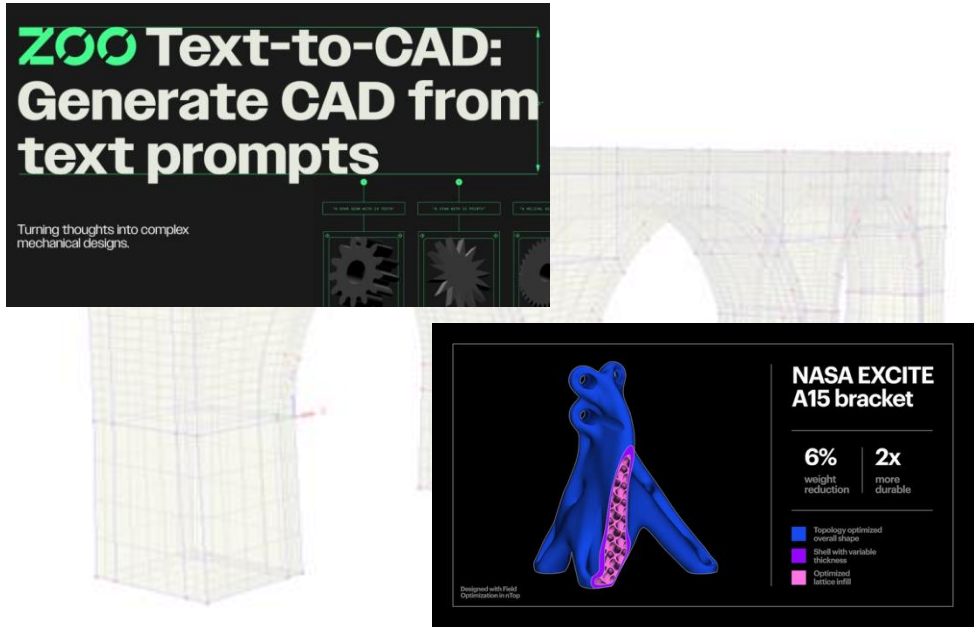




batch mode

New kids on the blocks

Computer-aided design (CAD)



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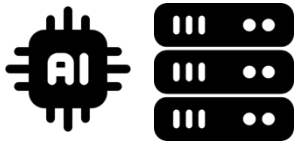

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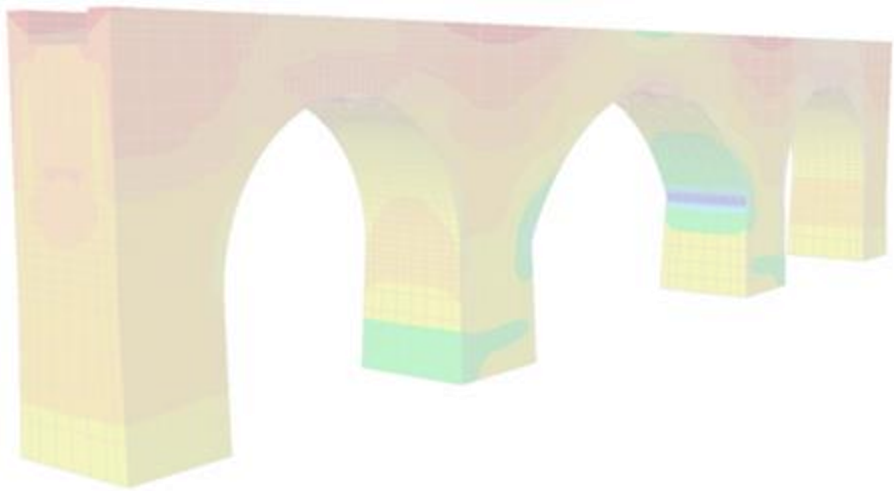

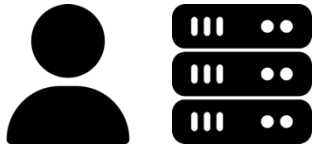

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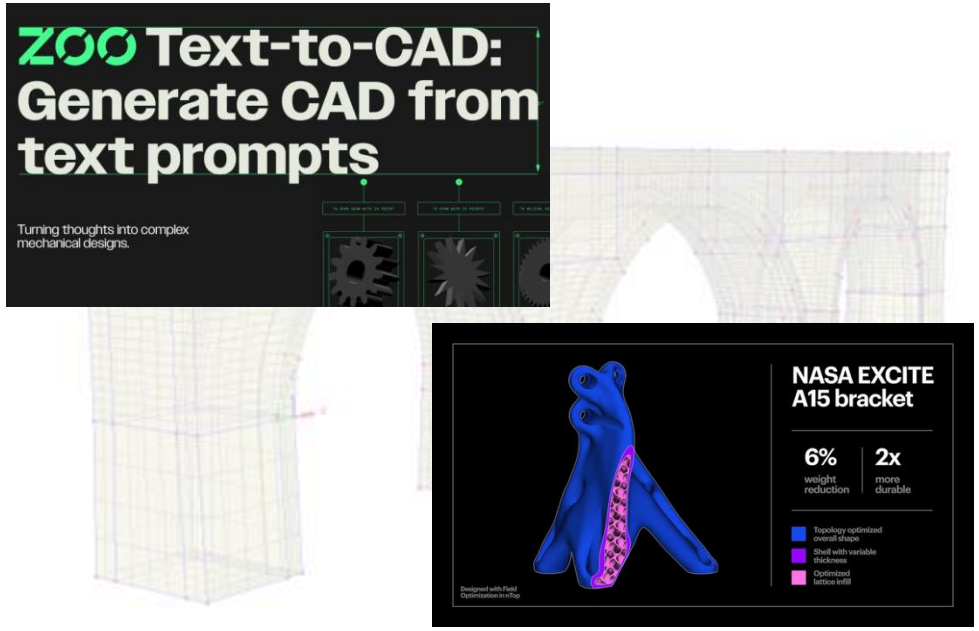

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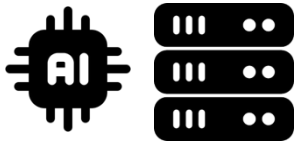
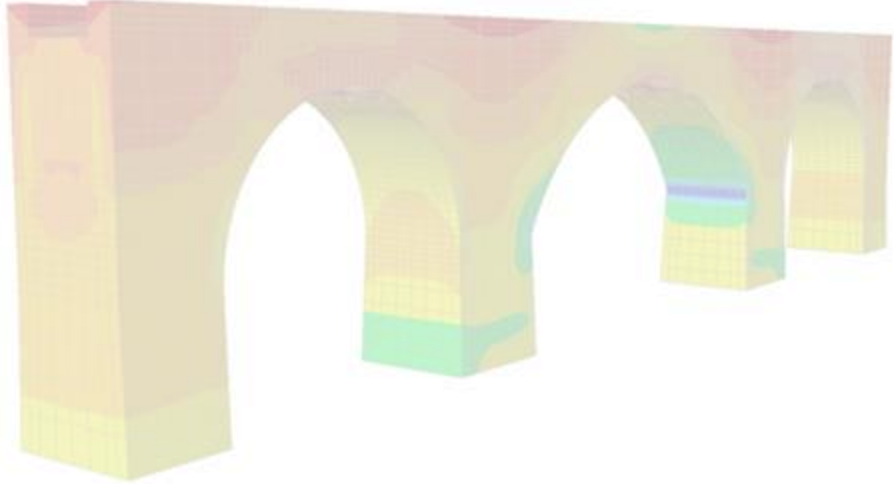
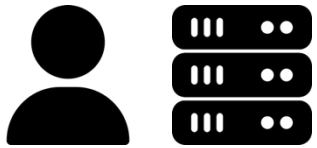


batch mode

Computer-aided engineering (CAE)

- reduced order models
- physics-informed machine learning
- data-driven models





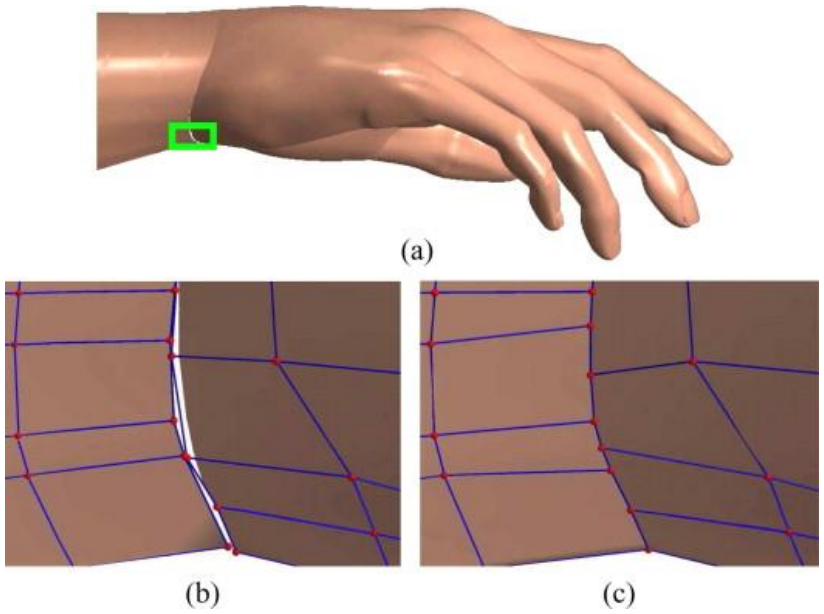
batch mode

online/offline mode

The incompatibility challenge

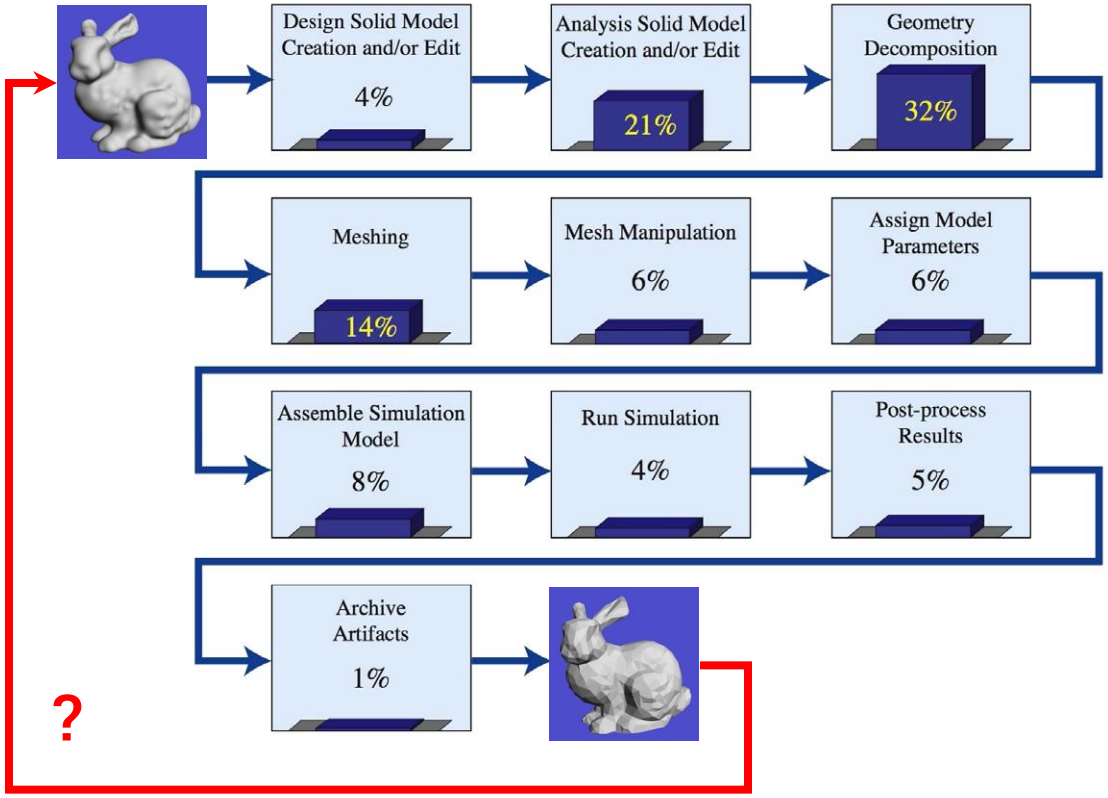
CAD: NURBS geometry models

- surface parameterizations (BRep)
- often non-watertight or trimmed
- often of poor ‘analysis-quality’



CAE: Finite Element Analysis

- time-consuming (manual) preprocessing
- no bidirectional link to ‘exact’ geometry



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- time-consuming (manual) preprocessing
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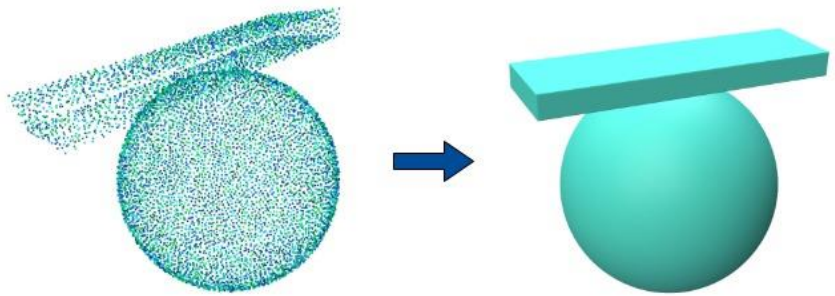
Text-to-CAD / generative AI for design

- at best same drawbacks as regular CAD
- often not even parametric geometry models

Physics-informed machine learning

- often ‘FEA-incompatible’ collocation formalism
- different convergence/consistency concepts



It needs more than just a technical solution

Possible technical solution: Isogeometric Analysis

- Perform CAD and CAE in the same mathematical framework → NURBS/B-splines

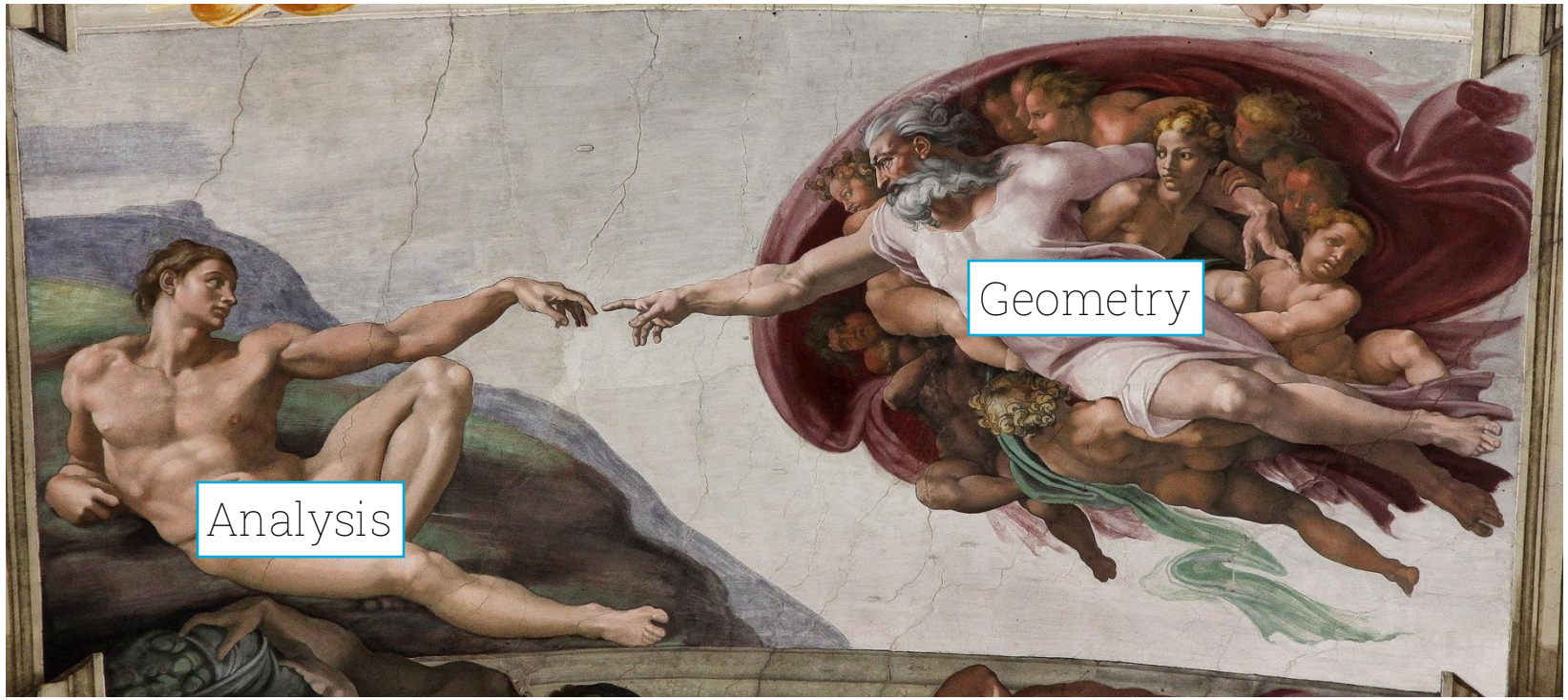


Figure 3.1 from J.A. Cottrell, T.J.R. Hughes, Y. Bazilevs: Isogeometric Analysis – Towards Integration of CAD and FEA

It needs more than just a technical solution

Possible technical solution: Isogeometric Analysis

- Perform CAD and CAE in the same mathematical framework → NURBS/B-splines

Remaining challenges

- BRep (CAD) ≠ VRep (CAE) → Volumetric CAD tools
- Usability of V-CAD tools for design → Automated volumetric parameterization tools
- Added value of V-CAD tools for analysis → **Design-through-Analysis** (DTA) workflows
- Integration of AI/ML based techniques → NURBS-based AI/SciML tools

DTAtools – An interactive collaborative DTA workflow

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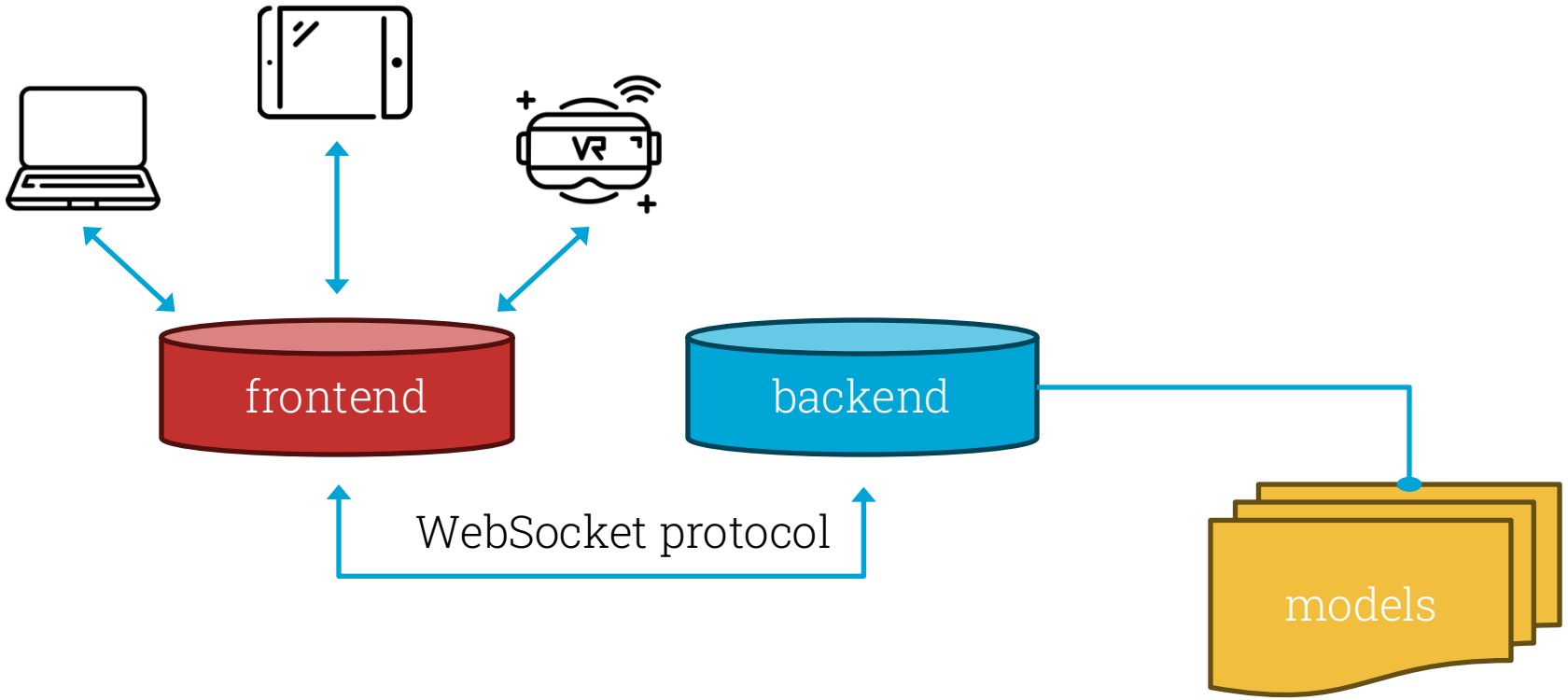
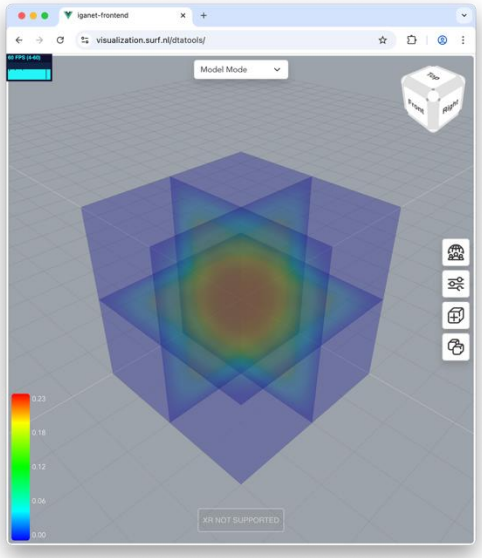
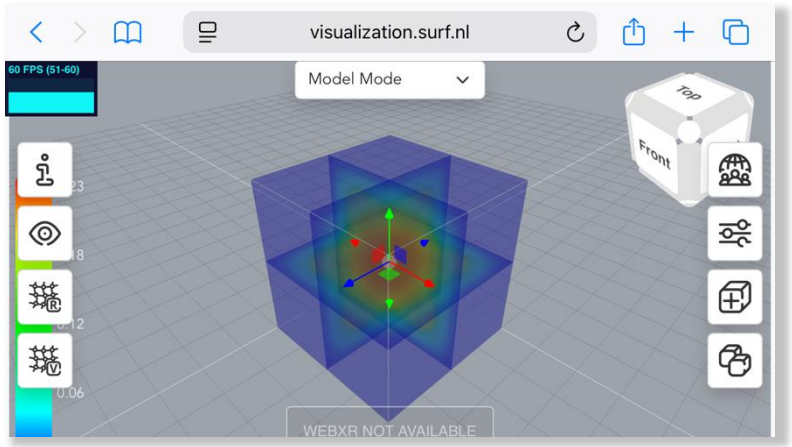
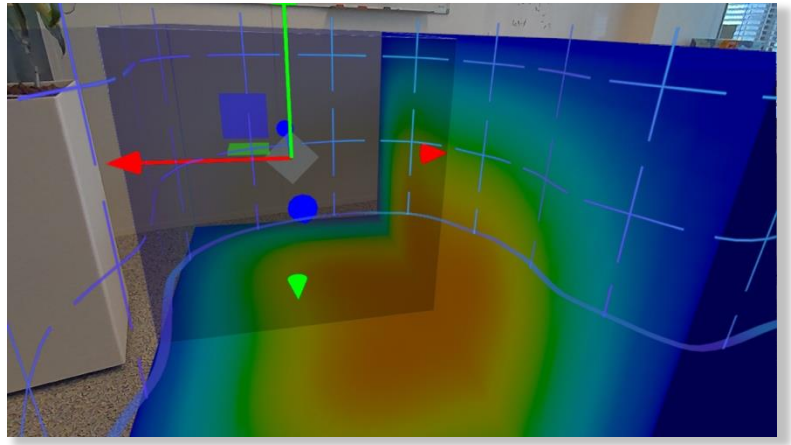
DTAtools – The vision

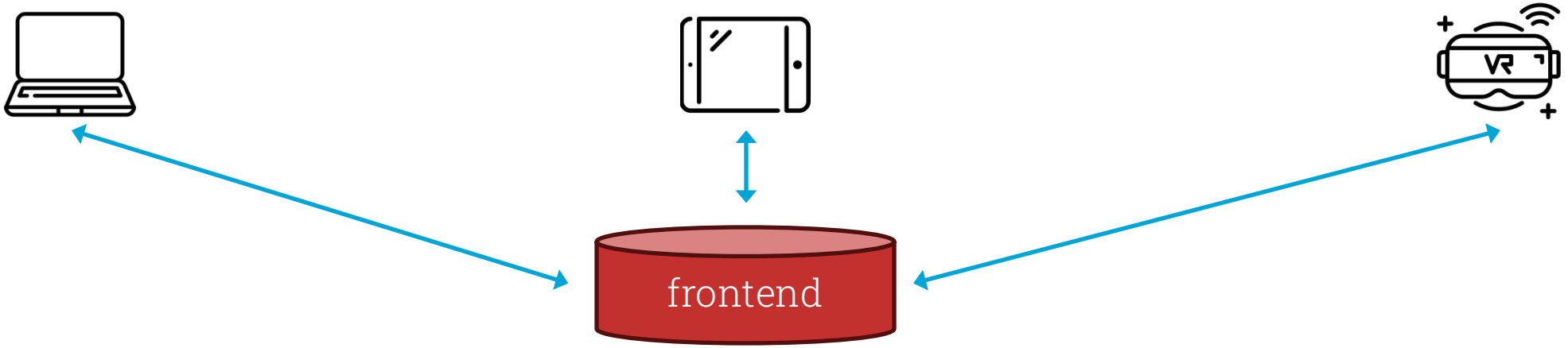


DTAtools – Reality check

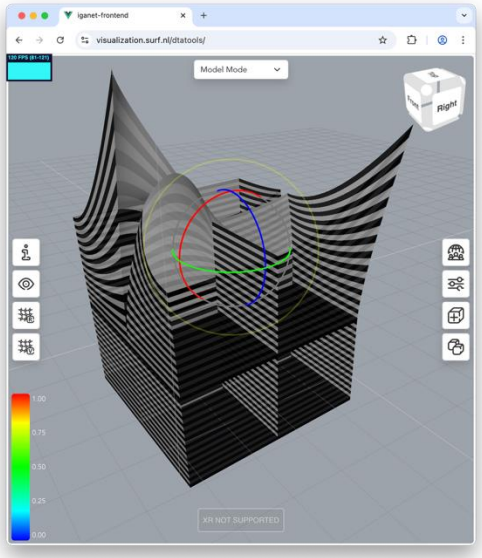


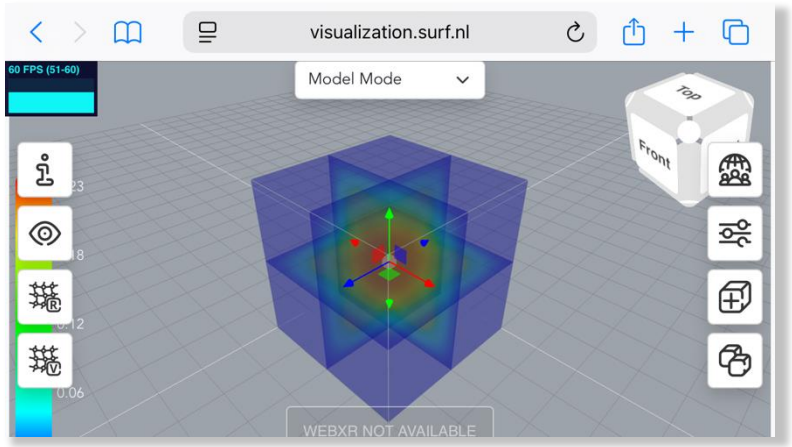


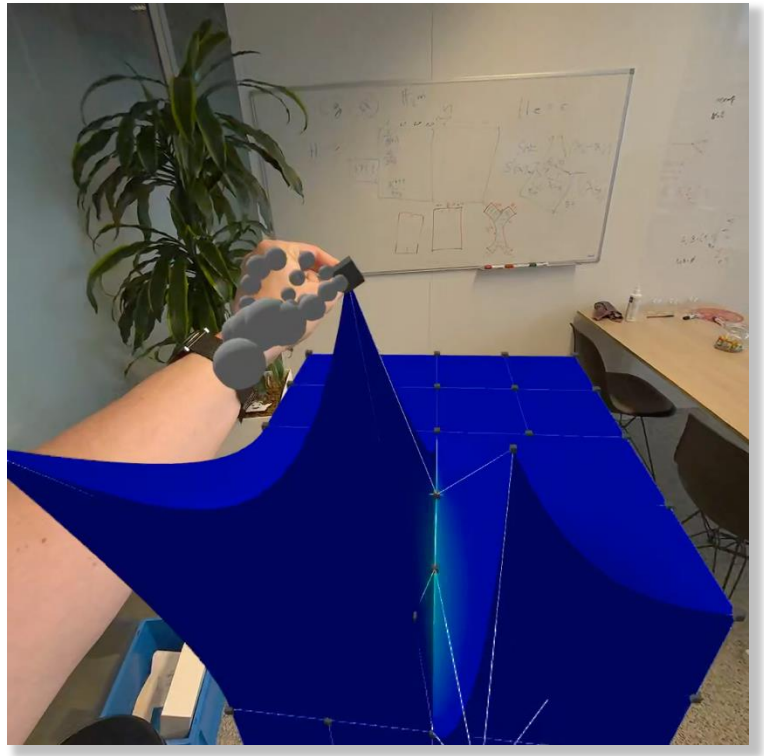


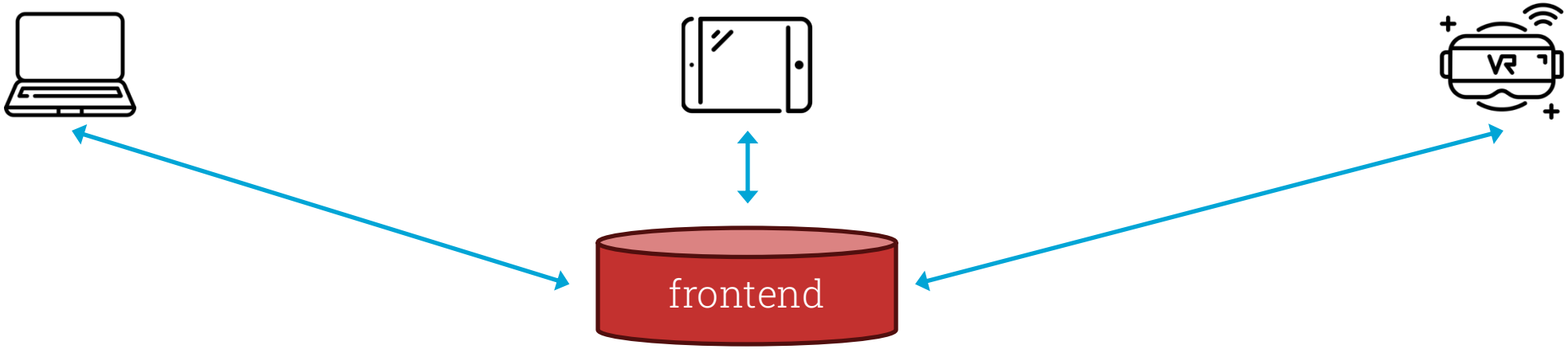


DTAtools – Diversify!



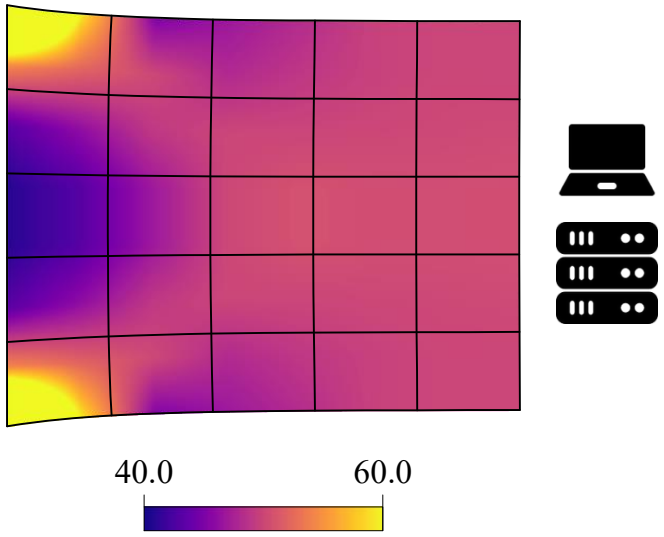


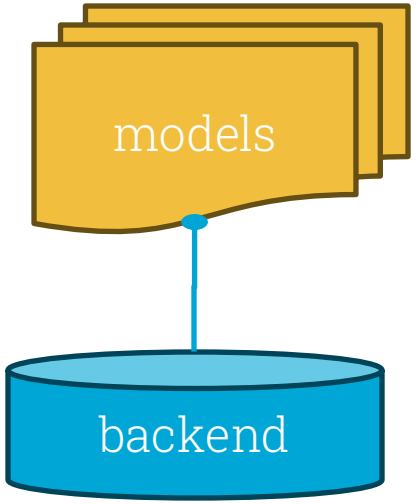




DTAtools – Accuracy vs. responsiveness

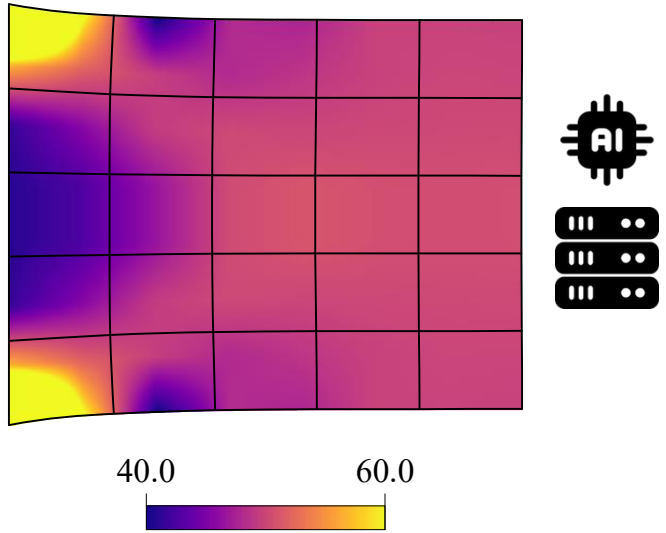
Geometry + Simulation Modules



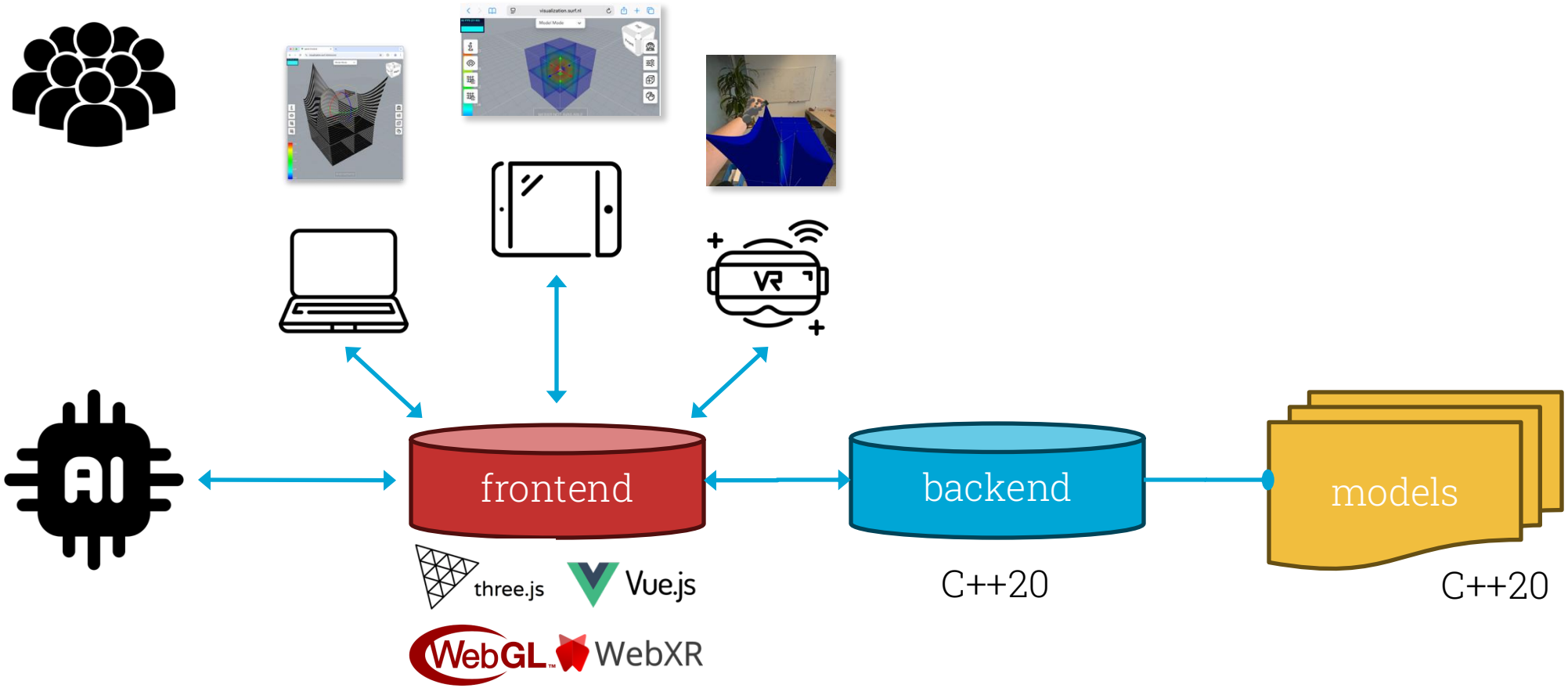


IgANets

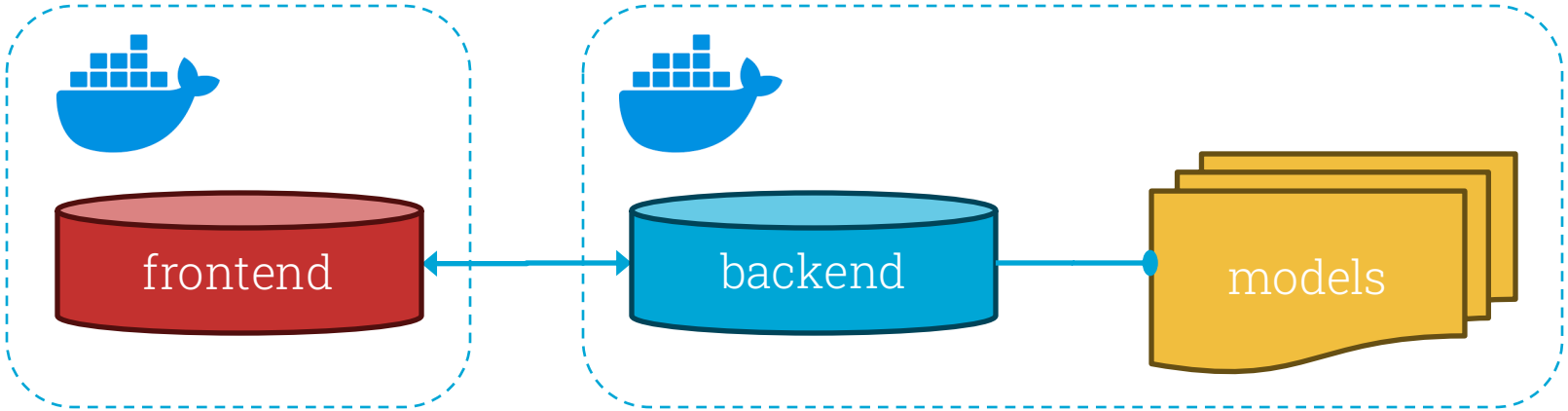
Isogeometric Analysis Networks



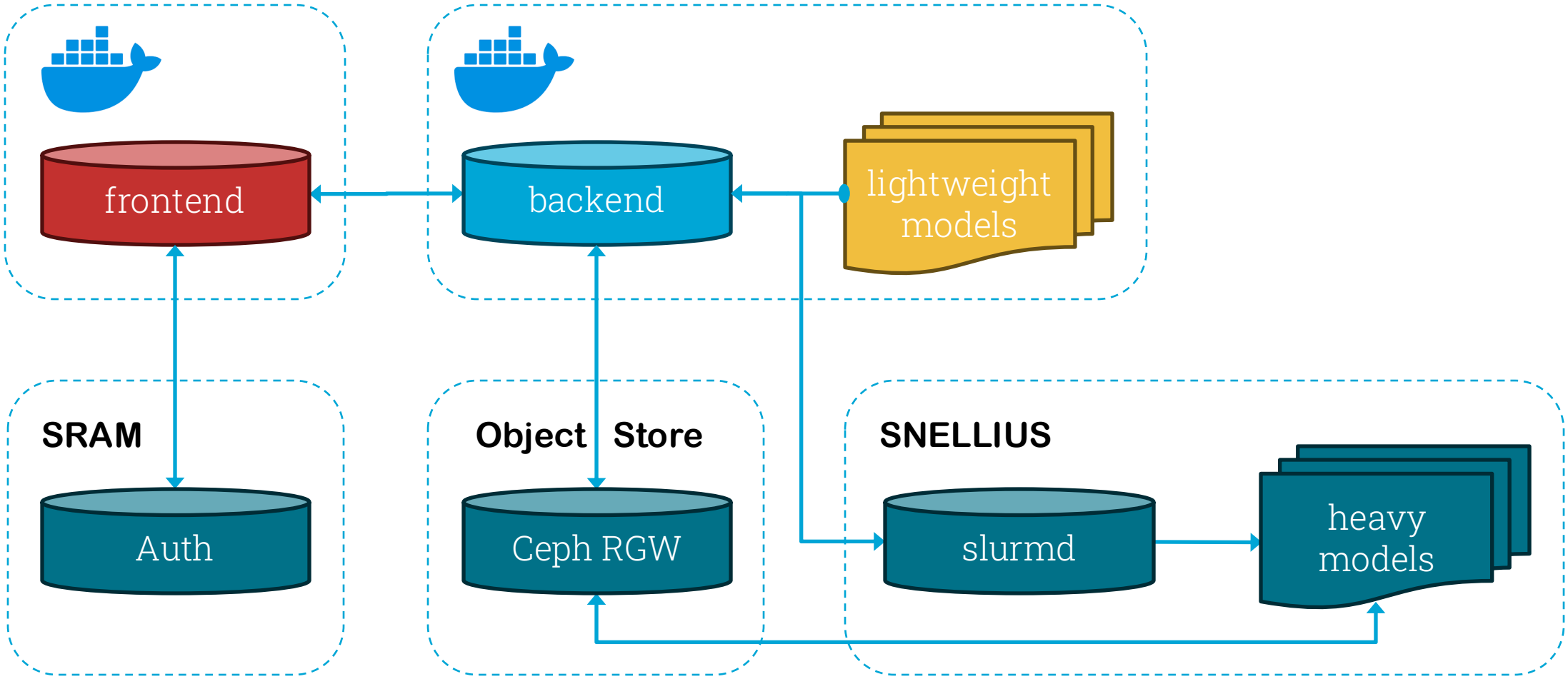
DTAtools – https://visualization.surf.nl/dtatools



DTAtools – Deployment strategy



DTAtools – Deployment strategy 2.0 [WIP]



Lessons learned & *open issues*

- Technical solutions alone are not enough, workflows need to be adapted
- It takes time to figure out the added value of new technologies such as XR
- Problems need to be solved when they occur, not ahead of time but also not too late
- *Usability of DTA workflow still needs to be evaluated at large*

Please contact us

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