Biomechanical modeling of soft tissue multiphysics using hybrid machine learning and finite element analysis

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A PhD candidate with background in:

- Biomechanics
- Multiphysics modeling
- Finite element analysis
- Machine learning

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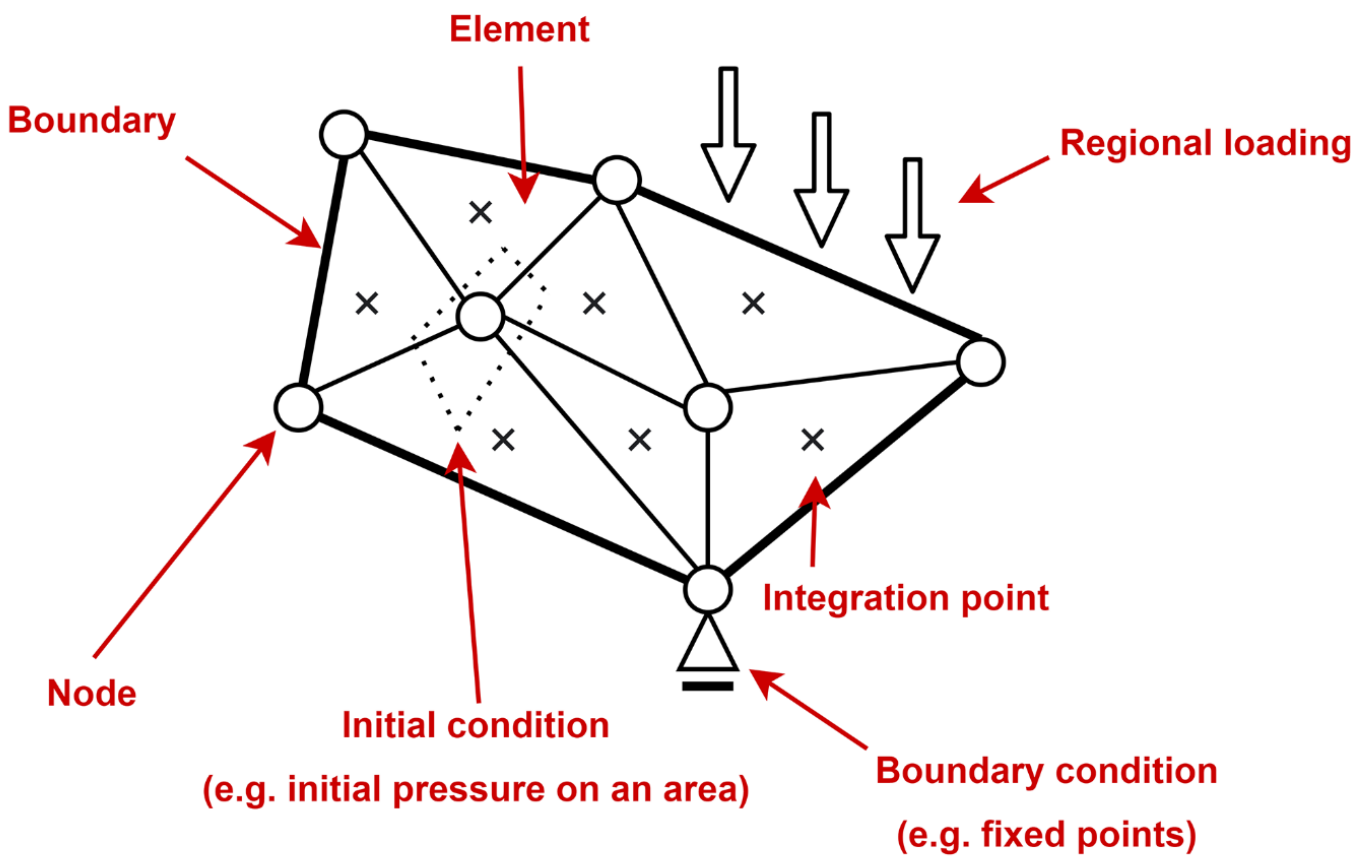
Introduction: finite element modeling



Limitations

- **Expensive**
- **Complex**

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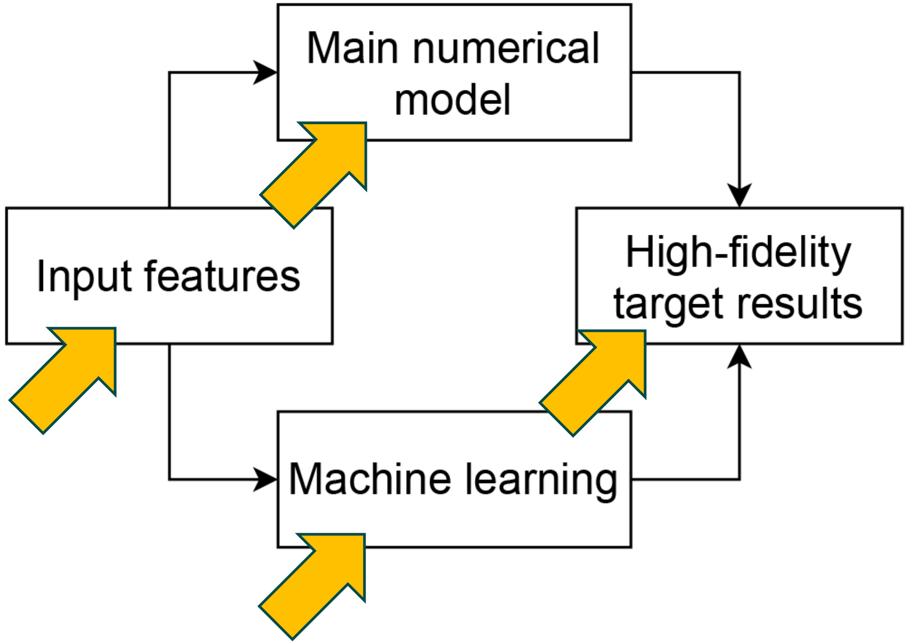
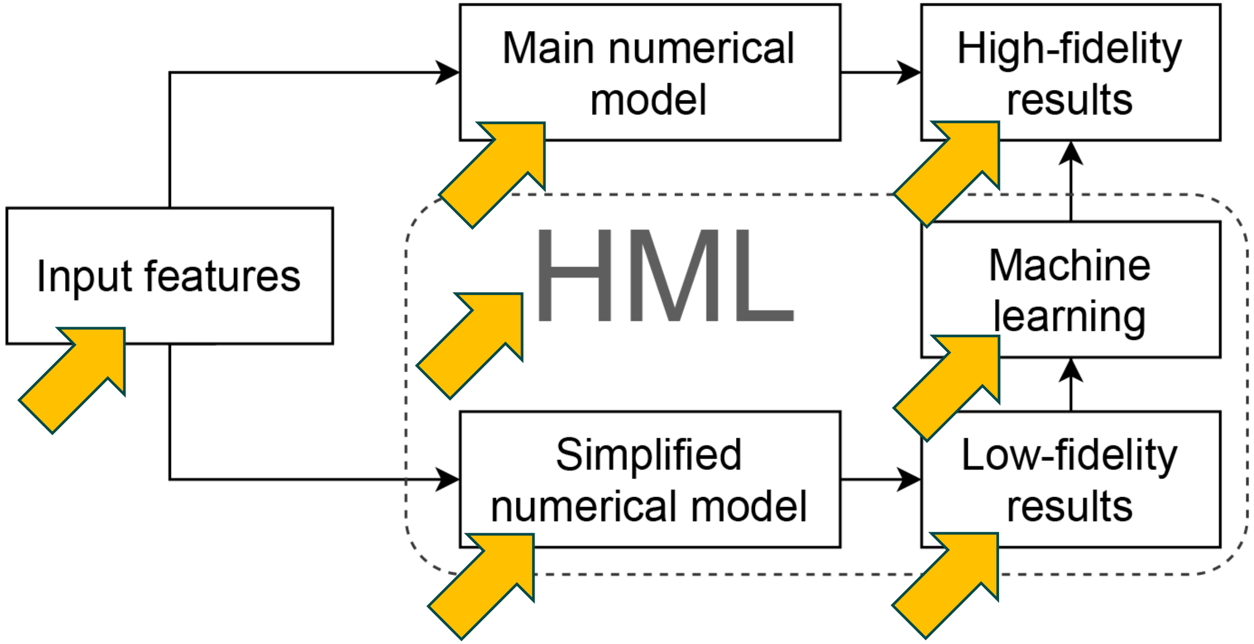
Methodology: surrogate modeling

Machine learning



Hybrid machine learning (HML)



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Methodology: multi-fidelity modeling

High-fidelity model

$$\nabla \cdot (\boldsymbol{\sigma}_T) = 0$$

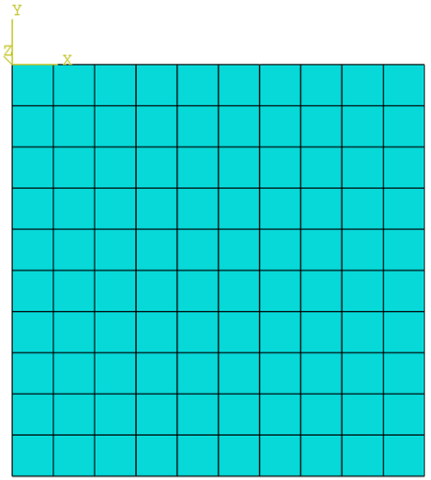
$$\nabla \cdot (\dot{\boldsymbol{u}} - \kappa \nabla p) = 0$$

Low-fidelity model

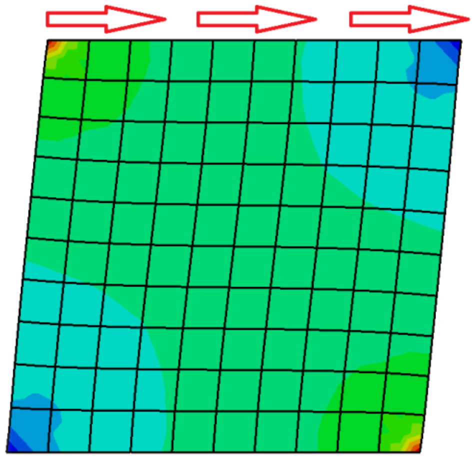
$$\nabla \cdot (\boldsymbol{\sigma}_{LF}) = 0$$

We use multiphysics!

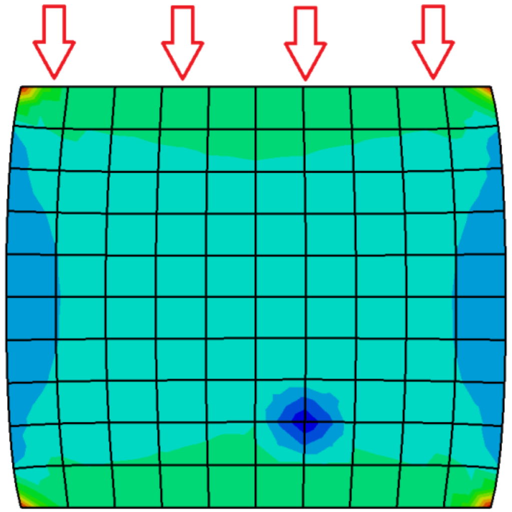
Methodology: 2D models



Initial condition



Under shear loading



Under axial loading

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Methodology: 2D models

Low-fidelity

Viscoelastic

↓

High-fidelity

Multiphasic

Machine learning models

- DL
- GB
- HML-DL
- HML-GB

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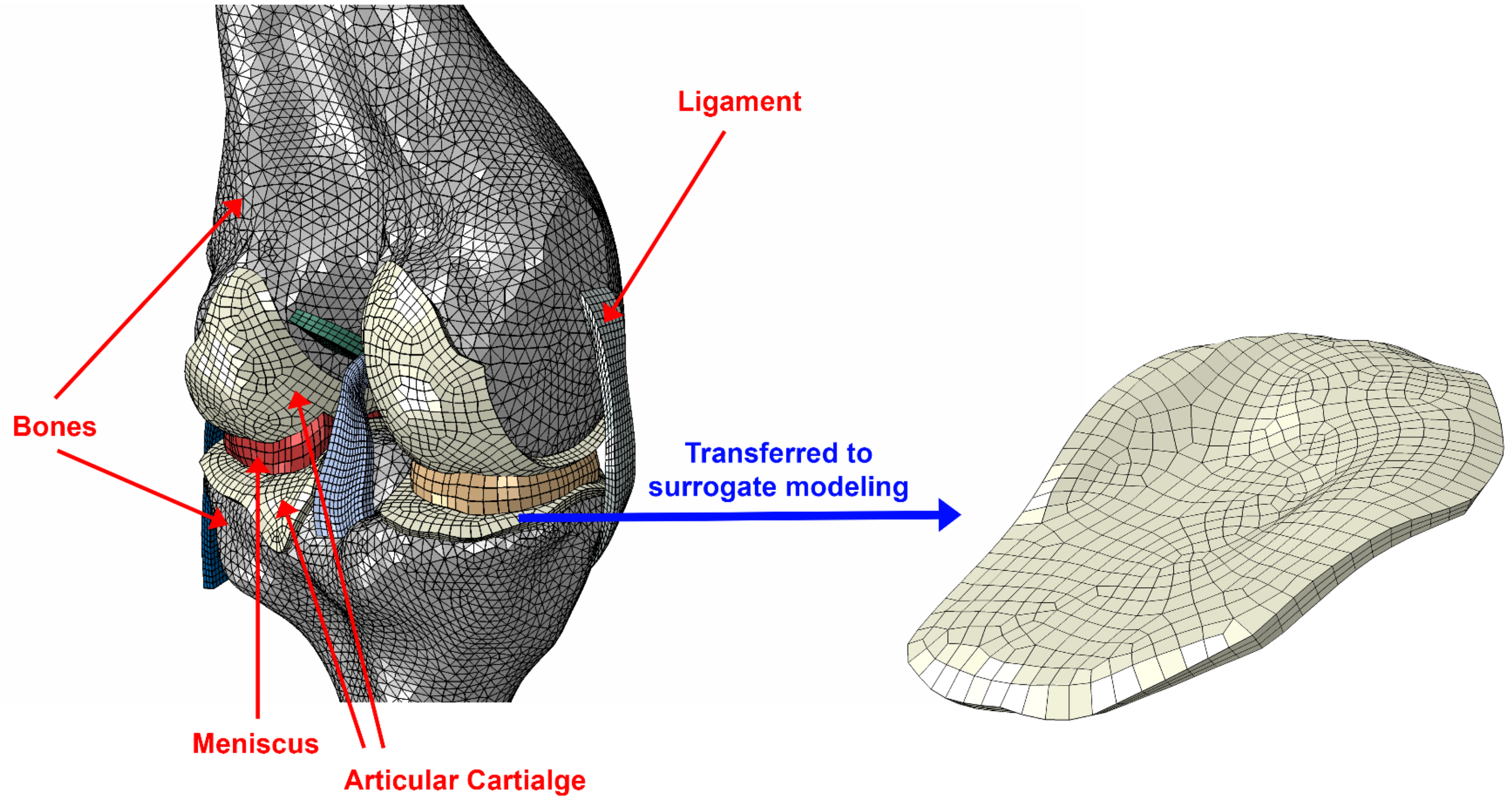
Methodology: 3D model



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Methodology: 3D model

Low-fidelity

Hyperelastic

↓

High-fidelity

Biphasic

Machine learning models

- DL-1
- DL-2
- HML-1
- HML-2

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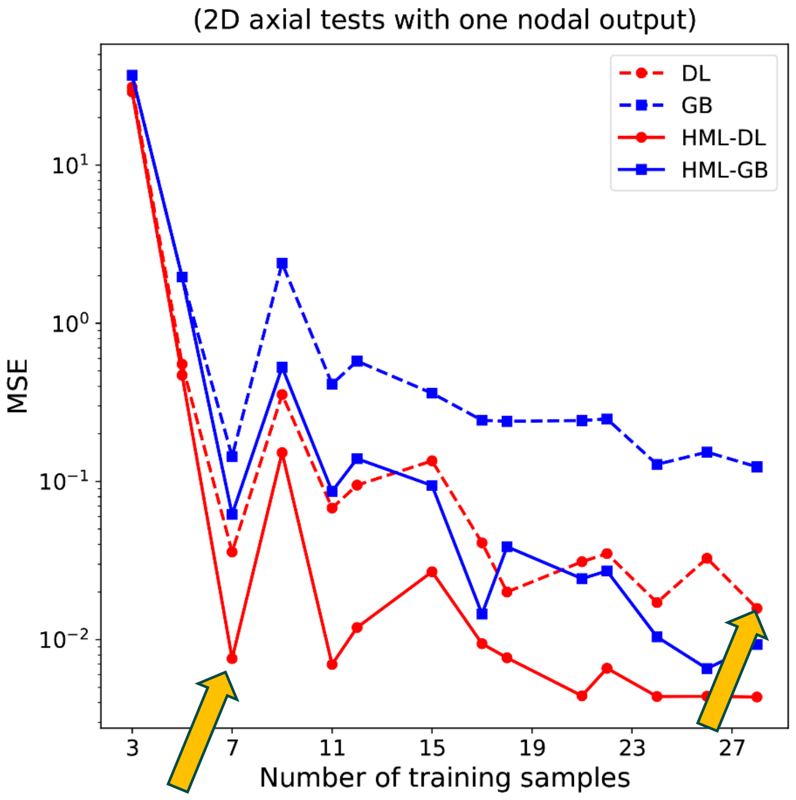
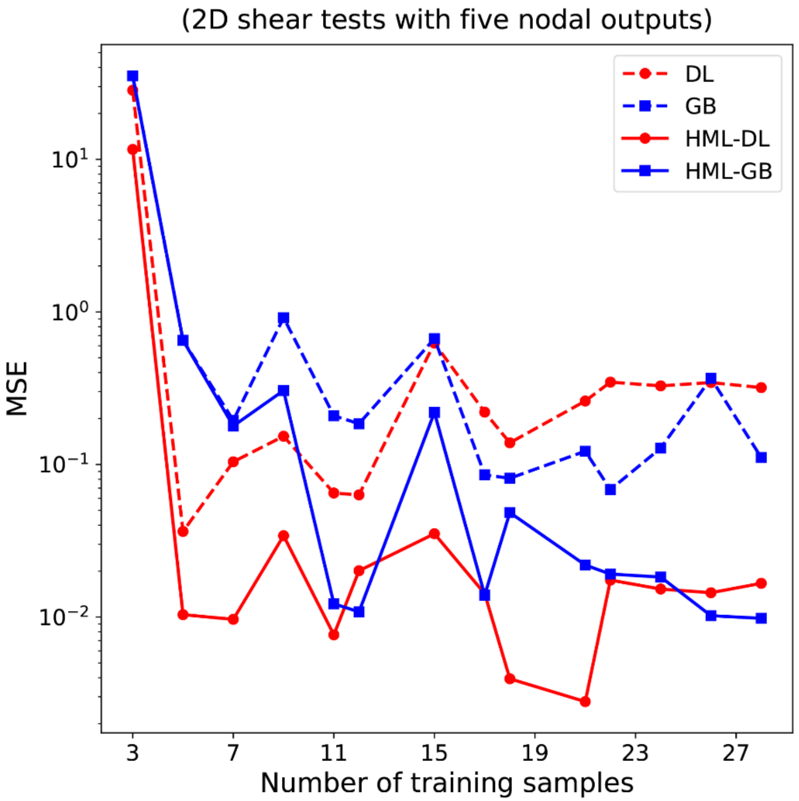
Results and discussion: 2D model





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Results and discussion: 3D model

#High-fidelity training samples	Surrogate model			
	DL-1	HML-1	DL-2	HML-2
13	0.055	0.009	0.033	0.015
26	0.047	0.034	0.049	0.011
39	0.174	0.049	0.060	0.016

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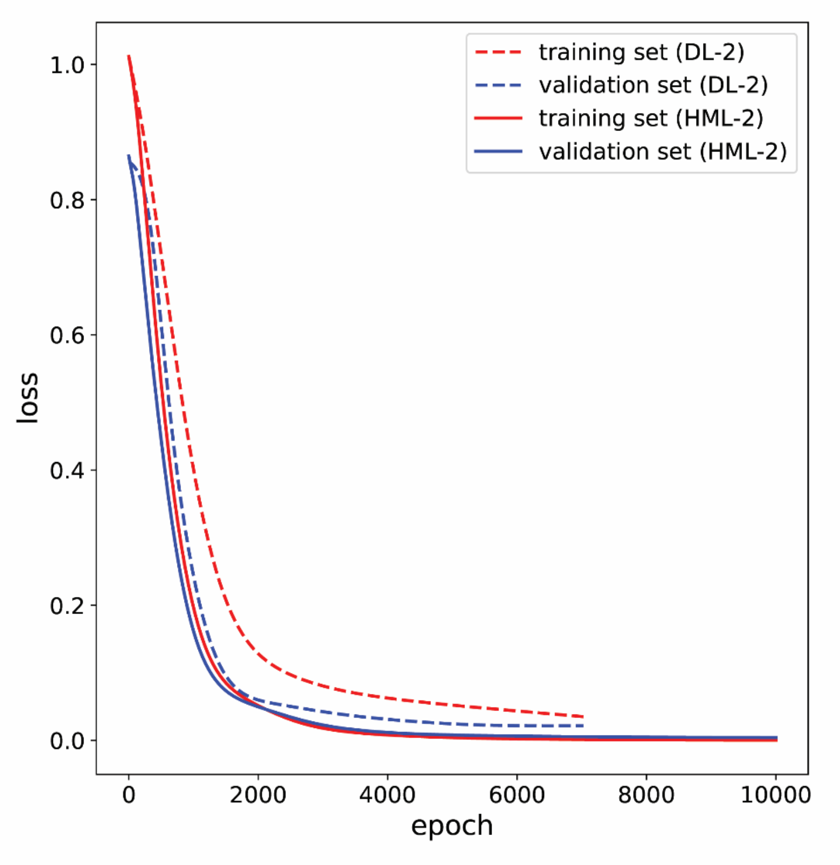
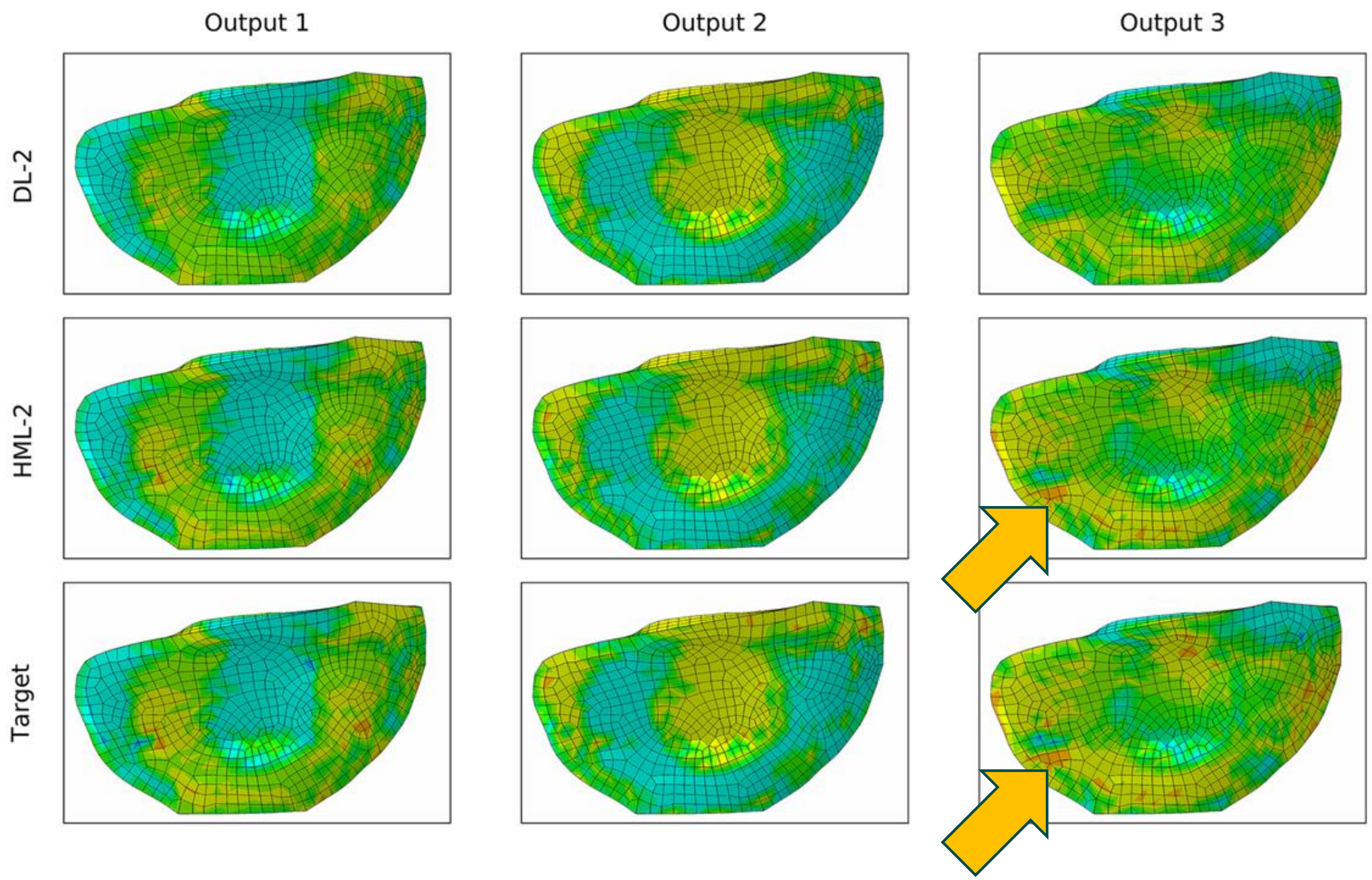
Results and discussion: 3D model





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Conclusions

Benefits	Implementation efficiency.
	Performance increase.
	8 to 19 times faster.
Limitations	Application of two numerical models.
	Longer training of the 3D model.
	Requiring tuning.

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[2] A. Erdemir, "Open knee: Open source modeling and simulation in knee biomechanics," *Journal of Knee Surgery*, vol. 29, p. 107–116, Oct 2014.

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