BRIDGING TISSUE-SCALE MULTI-PHYSICS TO ORGAN-SCALE BIOMECHANICS THROUGH MULTI-FIDELITY MACHINE LEARNING

Seyed Shayan Sajjadinia* (1), Bruno Carpentieri (1), Gerhard A. Holzapfel (2,3)

1. Faculty of Computer Science, Free University of Bozen-Bolzano, Italy; 2. Institute of Biomechanics, Graz University of Technology, Austria; 3. Department of Structural Engineering, Norwegian University of Science and Technology, Norway

*Corresponding author: e-mail: ssajjadinia@unibz.it

1. Introduction

Supervised machine learning is able to find every possible mapping between different but related datasets and can therefore be used as a scale-bridging approach by providing data samples from different scales. But in the context of computational biomechanics, generating high-fidelity (HF) data at the tissue scale (TS) might be straightforward (due to the simplified geometry), but collecting samples at the organ scale (OS) can be too expensive. This work aims to address this using a multi-fidelity machine learning (MFML) algorithm to bridge the scales, but without having to be trained on the expensive HF OS samples.

2. Materials and Methods

The proposed method is based on our recent MFML research [1], which defines the LF model by simplifying the multi-physics equations of the HF model. However, here we improve the generalizability of the trained to large-scale data, in particular through data augmentation, where the new pointwise data are interpolated. In order to empirically test the functionality of the proposed method (as shown in Fig. 1), the TS multi-physics data are created to train an MFML model with an advanced cartilage model [2], which is then applied to an OS geometry [3] for the large-scale simulation of cartilage multi-physics.

3. Results

The machine learning model is successfully implemented on the numerical TS data with a regular hardware setup. It enables the generation of complex multi-physics data in the OS articular cartilage models for further analysis.

4. Discussion and Conclusion

While a biomechanical OS model that contains complex multi-physics TS equations may need weeks of implementation, this approach yields equivalent results in less than a day (including dataset generation and model training) that can be generalized to other similar biomechanical models.

5. References

1. Sajjadinia SS et al., Comput Biol Med; 148: 105699 (2022).
2. Sajjadinia SS et al., J. Mech. Behav. Biomed. Mater; 114: 104203 (2021).
3. Erdemir A, J. Knee Surg; 29(2):107–116 (2016).

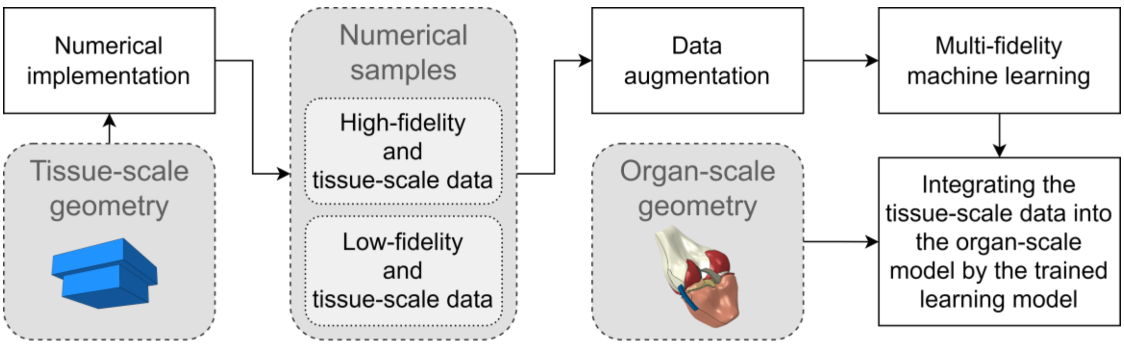

Figure 1. Workflow of the proposed method of multi-fidelity machine learning