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DATA-DRIVEN MULTISCALE COMPUTATIONAL MODELLING IN BIOMECHANICS USING CONVOLUTIONAL NEURAL NETWORKS

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Although computer assisted surgery is a very promising and fast-growing area, the increased computational cost of simulations is a significant drawback. The multiscale nature of Biomechanics simulations often results in a very fine discretization of the Geometry yielding intractable problems. Multiscale approaches are required to address this problem and give accurate results in a short time frame.

The aim of this project is to train a data-driven model that is later going to be used for performing the required simulations. This model should be able to extract features directly from images (MRI, CT Scan) and associate these features with quantities of interest such as the heterogeneous stress field (stress field calculated by considering the defects of the geometry). The parameters of that model can then be fine-tuned for every specific geometry.

In this work, for the purpose of feature detection, pretrained Convolution Neural Networks (CNN), such as VGG19/ VGG16, are used to detect the features of the examined geometry [1]. The number of features computed by the CNN is very large, so a Variational Auto Encoder (VAE) is used to compress the number of features without losing useful information [2]. Tensorflow, an open source machine learning library, along with Keras, an open source high-level neural networks API, is used for building and training the VAE. After that, locally fine scale FE simulations are performed to acquire the heterogeneous stress field around points of interest. ScanIP, a 3D image processing and model generation software developed by Synopsys- Simpleware, is used to segment the data and create the mesh [3]. FeniCS, an open source platform for solving PDEs, is used to perform the FE simulations. In order to associate the features with the quantity of interest, a Gaussian Process (GP) is used [4]. The GP also outputs the uncertainty of the prediction in terms of trust regions. When the model is used for a new image the maximum error of the prediction can be reduced, until reaching a desirable threshold, through a Bayesian optimization procedure where locally refined FE simulations will be performed at points that are more probable to present maximum stress. Linear elastic problems are investigated as a starting point.

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