Master thesis

Generation of a finite element model of a tibia head based on CT scans

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Background: Accurate simulation of bone mechanics is essential for applications such as implant design, fracture risk assessment, and pre-operative planning. In high tibial osteotomy, the fracture risk depends highly on the geometric and material configuration of the cortical bone.
However, current finite element models often use a homogeneous material distribution that does not capture the natural density variation in bone. Computed tomography (CT) scans provide grayscale images where the brightness, measured in Hounsfield Units, reflects tissue density (Figure 1). This density information can be used to assign a spatially varying material distribution to a finite element model. Integrating this information into a patient-specific 3D model has the potential to significantly improve simulation accuracy and clinical relevance.

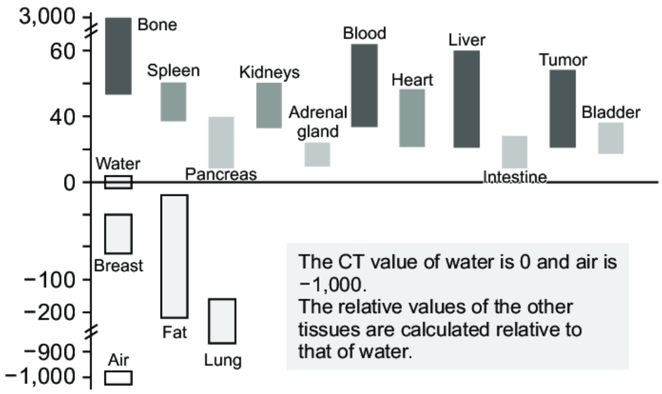

Figure 1: Hounsfield scale of CT values for various tissues (left) and CT image of a knee joint (right) [1,2].

Assignment: The overall objective of this work is to develop a workflow for reconstructing a 3D geometric model of the tibia head from CT scan data and to incorporate element-wise density distribution into the model for finite element analysis. The following steps are to be carried out:

- Literature review on CT-based modeling and existing approaches to heterogeneous material property assignment in FEM
- Processing of clinical CT image stacks: segmentation of the tibia head, extraction of bone contours at multiple slice depths, and reconstruction of a closed 3D surface model
- Generation of a volumetric finite element mesh from the reconstructed 3D geometry, distinguishing cortical and cancellous bone regions
- Mapping of Hounsfield Unit values from the CT data onto the finite element mesh and conversion to element-wise density distribution
- Comparison of the heterogeneous model against a homogeneous approach under representative loading conditions

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[1] – Jung, Basic Physical Principles and Clinical Applications of Computed Tomography, 2021.
[2] – Gelenkchirurgie Orthopädie Hannover: Fall. https://www.g-o-hannover.de/news_detail/News/Fall-Knie-mediale-Arthrose-im-Kniegelenk.