Eidgenössische Technische Hochschule Zürich
Ecole polytechnique fédérale de Zurich
Politecnico federale di Zurigo
Swiss Federal Institute of Technology Zurich

Computer Science Department
Prof. Dr. Peter Arbenz

Institute of Biomechanics
Prof. Dr. Ralph Müller
Dr. Patrik Christen

Efficient computational simulations of bone tissue remodeling

Proposal for a master thesis

Keywords: Micro-FE Analysis, Bone Remodeling Simulation, Micro-CT Imaging

Introduction

Local tissue loading is probably the most important factor triggering bone remodeling. To calculate tissue loading, micro-finite element (μFE) analysis is often used. In simulations of bone remodeling requiring iterative μFE analyses, an efficient way of updating the FE mesh has not been investigated, which is the purpose of this study.
Simulating how bones change due to disease and treatment would be a useful tool for clinicians supporting their treatment selection and prognosis. At the Institute for Biomechanics of ETH Zurich we have developed a computational model of bone remodeling that is based on tissue loading calculations from micro-finite element analysis. The FE solver in use at the institute was developed and implemented at the Computer Science Department of ETH Zurich (Peter Arbenz). An example tissue loading calculation is shown in Fig. 1 for the human distal radius. Since μFE models are derived from micro-CT images, these models can contain hundreds of millions of elements and are thus computational time intensive. In our current implementation, a μFE analysis is performed in each simulation-iteration but it has not been investigated yet how to efficiently update the FE mesh from one iteration to the next one and how the solution of the FE analysis of one iteration might be used in the proceeding iteration. It is expected that there is potential to reduce the required computational time for such iterative bone remodeling simulations.

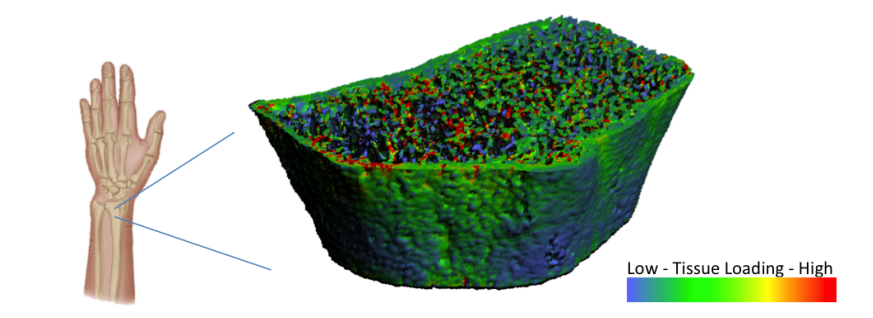

Figure 1: Tissue loading for the human distal radius

Scope of work

The student will study the implementation of our FE solver (ParOSol), how the FE results are stored (HDF5), the functioning of the bone remodeling algorithm, and delve into the respective literature in order to come up with a solution to update FE meshes in bone remodeling simulations. The project is thus suited for students with an interest in computational science, programming (C++), and image analysis. This is a joint project between Prof Peter Arbenz of the Computer Science Department and Prof Ralph Müller of the Department of Health Sciences and Technology at ETH Zurich.

Description of the task

The goal of this master thesis is to

1. Investigate the efficient representation (storage) of FE meshes that vary in time.
2. Investigate how information can be transferred from one mesh to the next to generate good initial approximations (vectors) for the next simulation.

The task is 90% computational, 10% image analysis.

Procedure and deliverables

- After 3-4 weeks: short 15 minute talk on project, including a schedule with tasks & milestones.
- There will be frequent meetings to check the progress of the work.
- The work is to be documented in a short and concise thesis (LaTeX, PDF). It must be written such that it is intelligible to a fellow-student.
- The thesis is to be presented in a 30 minutes talk.
- The code should be written as clean as possible. It must be complemented by a short user's guide.

Contact

- Prof. Dr. Peter Arbenz, Computer Science, ETH Zurich, arbenz@inf.ethz.ch
- Dr. Patrik Christen, Institute for Biomechanics, ETH Zurich, patrik.christen@hest.ethz.ch,
- Prof. Dr. Ralph Müller, Department of Health Sciences and Technology, ETH Zurich.

Dec 16, 2014. P. Arbenz