Acoustics meets Bones

Software Lab Project 2013 – Chair for Computation in Engineering

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Abstract

A software for the simulation of the wave equation in bones was developed. It was demonstrated that the concept of time reversal in combination with artificial sensors can be used to trace the origin of acoustic waves in bones.

Introduction

- Micro cracks occur in bone before the bone fractures.
- Signals of acoustic emissions can be measured with sensors on the bone surface.
- The origin of micro cracks is unknown and shall be determined by numerical simulation

Figure 1: Compressional testing of a bovine bone; from [1]

Theory

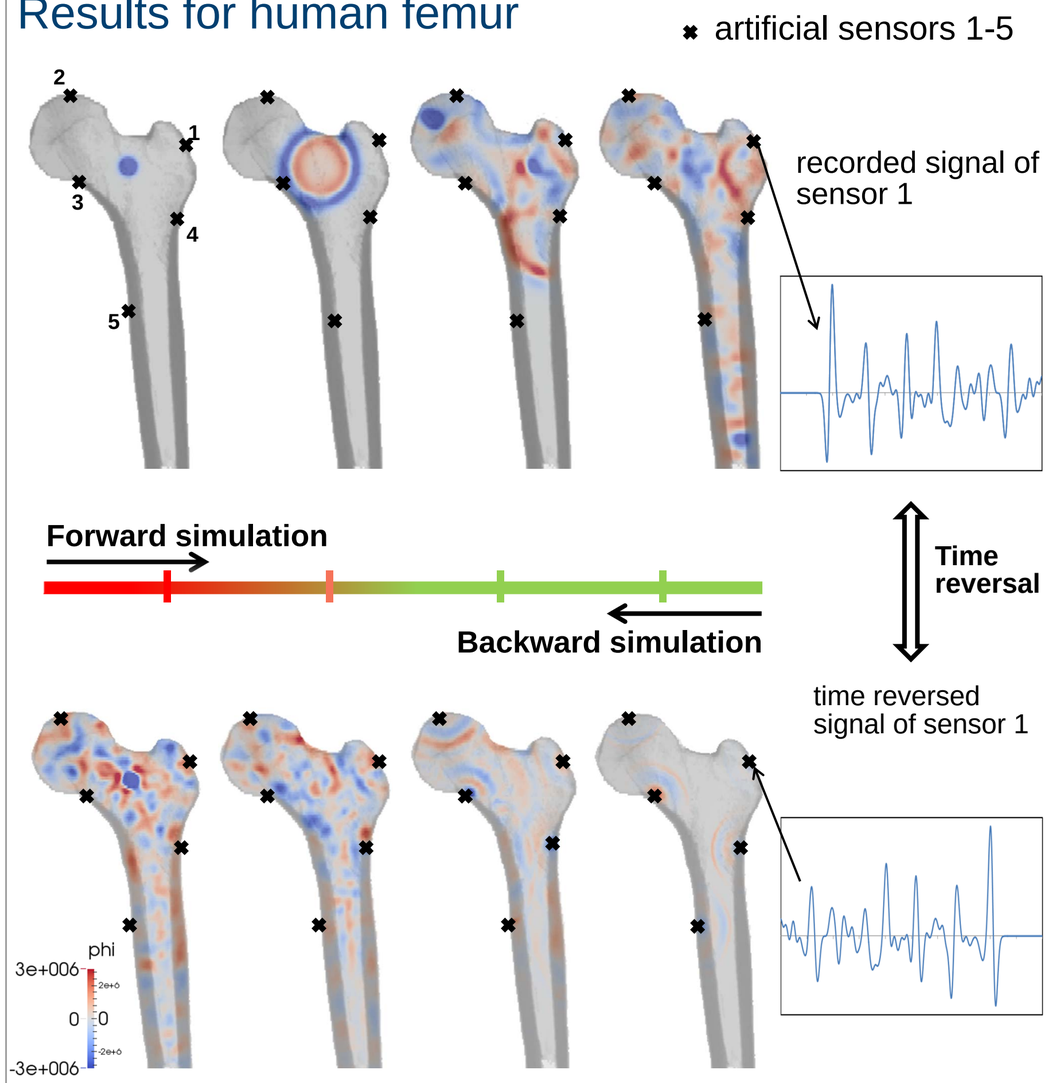
- Propagation of accoustic waves is described by the **wave equation**

$$\frac{\partial^2 \Phi}{\partial t^2} = \alpha^2 \Delta \Phi$$

- The concept of **time reversal** is used to retrace accoustic waves back to their origin (location of micro crack).
- The wave equation is discretized by the **Finite Difference Method**.

$$\Phi_{i,j}^{new} = 2\Phi_{i,j} - \Phi_{i,j}^{old} + \Delta t^2 \cdot {\alpha_{i,j}}^2 \cdot \left[\left(\frac{\partial^2 \Phi}{\partial x^2} \right)_{i,j} + \left(\frac{\partial^2 \Phi}{\partial y^2} \right)_{i,j} \right]$$

Results for human femur



Implementation

Object-oriented C++ code designed for 1D-, 2D- and 3D-problems

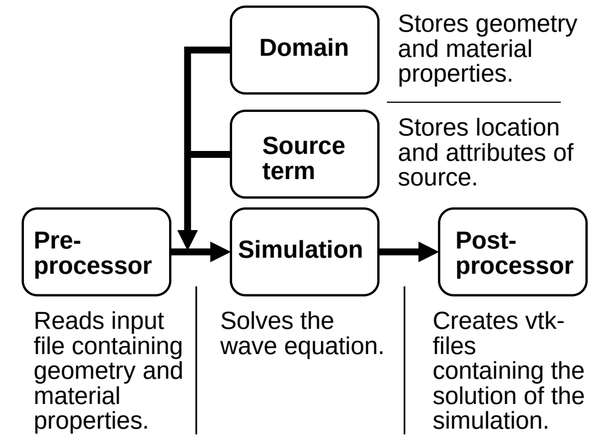


Figure 2: code structure

Conclusion and Outlook

- Simulation was done for 1D-, 2D- and 3D-benchmark domains.
- Concept of time reversal can be used to find the approx. location of micro crack events.

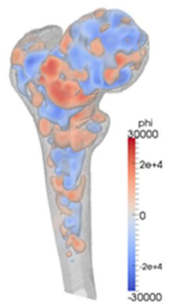


Figure 3: 3D-simulation

Next steps:

- Verifying and Validating results
- Parallelization and optimization
- Parameter study, e.g. varying sensor locations and velocity model

References

[1] Fabian Malm, “Schallemissionsanalyse am humanen Femur“, Master‘s Thesis, Chair of Non-destructive testing, TU München, 2012