Student project: <u>Medical attenuation tomography</u>

This project will allow you to delve into the field of medical ultrasound tomography. Seismology has provided us with a very broad and powerful toolbox to analyze and understand wave phenomena at any scale. Therefore, the application of these methods is not limited to geophysics, but can be transferred to many different fields of research dealing with wave propagation problems. A particularly active synergy has developed between seismology and medical ultrasound (Duric et al. 2009, Hopp et al. 2019, Korta Martiatu et al. 2020). Gerhard Pratt presents a very nice overview of the differences and similarities between the two fields of research (Pratt et al. 2017). In both cases, ultrasonic waves are used to probe an unknown medium and to acquire some data from which one would like to infer the structure of this medium. In geophysics, the medium of interest is the Earth (or some part of it), whereas in medical ultrasound one is interested in obtaining tomographic images of the human body that display the structure of human tissue and provide the basis to differentiate different tissue types. The latter is especially interesting in the context of cancer screening, where the goal is to identify malignant cell regions using tomographic images. This identification essentially builds on the accuracy of the reconstructed sound speed values in various soft tissue types, such as fat, liver, or brain tissue. Analogously, the interpretation of tomographic images in seismics critically depends on the accuracy of the reconstructed pressure and shear wave velocity distributions.

An additional parameter besides the velocity structure that influences the signals arriving at the receivers is the attenuation of energy experienced by the wavefield as it travels through the medium. In human tissue, these attenuation losses are more significant than in sedimentary rocks, which motivates the inclusion of attenuation as an additional model parameter to be reconstructed in a tomographic inversion. Combining the sound speed reconstruction with the additional information of attenuation losses along ray paths may further increases the sensitivity and specificity of the interpretation in a medical setting and has been shown to be effective for multiparametric tumor detection and characterization in breast cancer screening (Li et al. 2008, Hooi et al. 2016, Wiskin et al. 2017).

In this project you will have the chance to work on an in-vivo data set containing a cross-section through a living mouse (Lafci et al. 2020, see Fig. 1). This is very exciting since real medical data sets are hard to get your hands on as a seismologist. Since mice share many biological similarities with humans, they are preferred study objects throughout medical research and experiments on mice are generally a frst necessary step towards human experiments. The goal of the project is to reconstruct the sound-speed as well as the attenuation distribution of the tissue using straight-ray tomography. The approach to obtain an image of the sound speed distribution is conceptually very similar to the steps involved in a seismic transmission experiment. First, travel time data between an ultrasonic source and a receiver are collected. These data are then used to invert for the sound speed distribution of the tissue. The same algorithm may then be modified to reconstruct the attenuation distribution of the tissue.

A road map for this project includes an initial phase of getting familiar with the data set and to preprocess the data. In a second stage, you will work on the expansion of the existing straight-ray tomographic inversion workflow to additionally reconstruct attenuation values. The existing code is written in python and some prior coding experience would be ideal, however, this is not a strict prerequisite. You are free and even encouraged to experiment in the implementation step. If you are interested in parallel computing, high performance computing and the like, then this is the stage where you can get creative and use your computation powers!

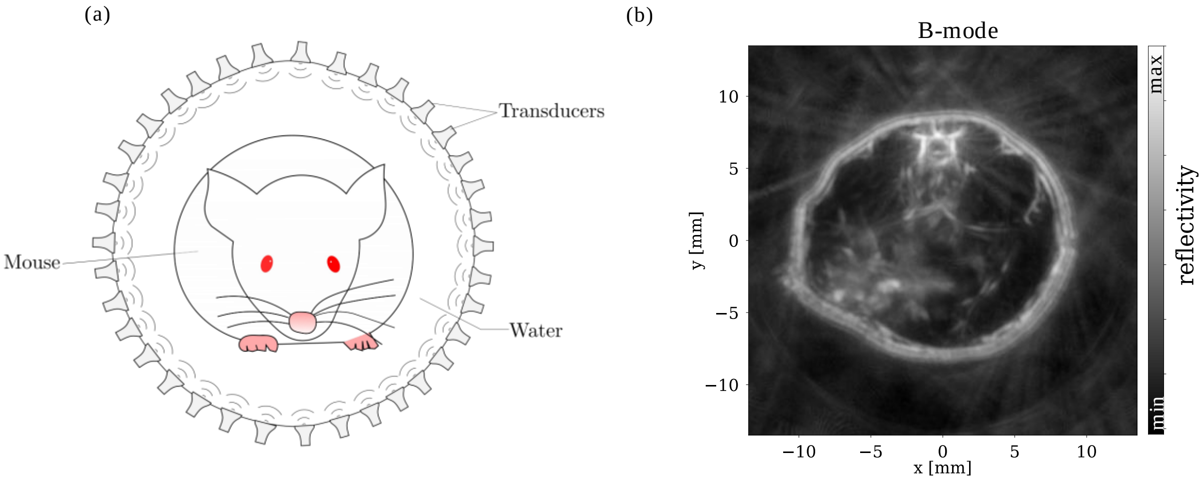

Figure 1: (a) Sketch of the data acquisition device and (b) a reflection image of a cross-section through the mouses' abdomen showing the impedance contrasts. Especially striking is the high contrast at the vertebral column, a bone structure, on top.

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