PhD9

BIOQIC

# Robust recovery strategies for the acoustic inverse scattering problem in anisotropic systems

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**Application Area:** Cardiovascular, Cancer **Modality:** PAT, US **Related:** PhD 2, 4, 5, 6, 7

## Background

Inverse scattering problems occur in medical imaging in various ways with the acoustic inverse scattering problem related to, e.g. PAT and elastography being of particular importance. In current approaches to reconstruction, the acoustic properties of the objects of interest are often assumed to be known a priori or locally constant, which is not a valid assumption in heterogeneous tissue. This limits not only the significance of the images but also the quantitative accuracy of parameters derived from PAT or elastography.

## Hypothesis

Mathematical anisotropic systems for regularization allow improved recovery strategies for a variety of inversion-based imaging methods.

## Methods

During this project, we will develop robust recovery strategies based on anisotropic systems[1,2] for regularization to solve the 3D acoustic inverse scattering problem. Experimental methods are centered on PAT and elastography in both MRI and ultrasound.

## Work Packages

**WP1: Model development**

**WP2: Anisotropic regularization systems**

**WP3: Phantom construction/data acquisition/reconstruction tests**

← *year 1* → ← *year 2* → ← *year 3* →

**WP1:** Introduction of a mathematical model for 3D scatterers to account for anisotropic features prevalent in biological tissues such as connective tissue fibers, blood vessels, or lactiferous ducts.

**WP2:** Development of adapted regularization strategies such as the l1-norm of carefully chosen representation systems capable of sparsifying the model functions and aimed at providing an optimal sampling-reconstruction scheme in terms of approximation accuracy. Analysis of this scheme with respect to realistic noise assumptions and model uncertainty, and application to experimental data obtained by PAT and MRI elastography.

**WP3:** Development of a numerical multimodal tissue phantom, including tissue-like heterogeneities such as connective tissue fibers or blood vessels, and of new recovery strategies with particular emphasis on quantitative estimation of the uncertainty in the determined parameters due to, for example, noise.

## Clinical Translation

This project is strongly focused on basic research and the demonstration of fundamental physical principles associated with acoustic scattering, inverse problems, and their potential application to biomedical imaging in proof-of-principle studies.

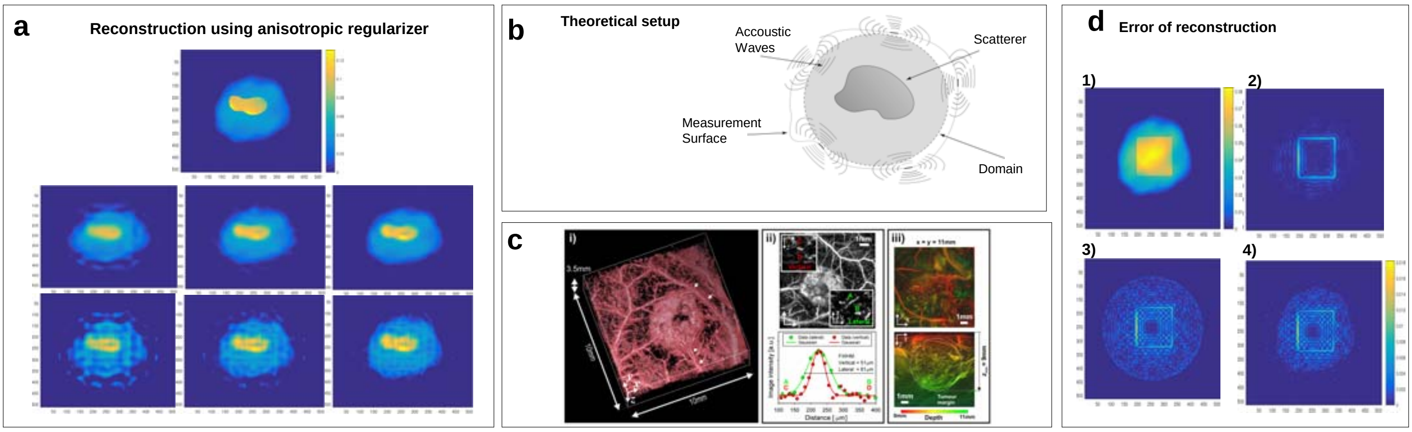


**Figure:** Reconstructions from acoustic measurements using shearlet regularization. a) Comparison of reconstructions of top image using shearlet regularization (second row) against standard Tikhonov regularization. b) Theoretical setup of the scattering problem, c) 3D photoacoustic image of a subcutaneous tumour and the surrounding tissue region. (i) volume-rendered image of the vasculature, (ii) maximum intensity map of the image data set shown in (i) with cross-sectional images (insets) of small blood vessels together with their lateral and vertical dimensions, (iii) maximum intensity maps of a 3D image data set of a large tumour with an imaging depth of 9 mm, d) Analysis of the error of the reconstruction of 1). The shearlet regularizer was used to obtain 2), the unregularized problem yields 3), Tikhonov regularization yields 4).

**Literature**

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