Abstract

Coupled-physics methods are recently introduced techniques which combine two or more different types of waves to reconstruct images of biological tissues. These methods were developed to overcome the limitations of the classical techniques of tomography. We will discuss some of the factors motivating the need for new modalities in the introduction. Then, we will consider the forward and inverse problems arising in two ultrasound-based coupled physics modalities, namely thermo- and photoacoustic tomography (TAT/PAT) and magnetoacoustoelectric tomography (MAET).

TAT/PAT is the most developed of the coupled physics modalities. In order to obtain images, the initial acoustic pressure in a body must be reconstructed from time series of pressure measured on a surface outside of the body. By now, many techniques for the reconstruction are well known. Most of these methods assume measurements are made on a surface which completely surrounds the object of interest. However, in practical applications, data is only available on a surface which partially surrounds the object. Under the assumption of constant speed of sound, we develop an explicit, non-iterative reconstruction procedure for the inverse problem of TAT/PAT. Our method recovers the initial acoustic pressure up to an infinitely smooth additive error term. Numerical simulations show that this error is small in practical terms. We also present an asymptotically fast implementation of this procedure for the 2D problem with data given on an arc of a circle.

MAET, also known as Lorentz force impedance tomography or Hall effect imaging, is a novel coupled-physics modality for reconstructing images of the conductivity distribution inside biological specimens. It was designed as a high-resolution alternative to the better known electrical impedance tomography (EIT), which is only capable of producing very low resolution images, which are impractical for diagnostic imaging. In contrast to TAT/PAT, MAET is in the very early stages of its development. We present some of the mathematical theory developed for a 2D version of MAET in a circular chamber with point-like electrodes immersed in a saline solution surrounding the object. Numerical algorithms for solving the forward and inverse problems of MAET in this setting are also developed. The work of these algorithms is demonstrated in several numerical simulations.