Estimation of the effective sound speed in an acoustic medium

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The emergence of quantitative medical imaging techniques constitutes a major shift of paradigm for the theory of inverse problems. Imaging modalities are now expected not only to produce an image but quantitatively reconstruct parameters of interest. In an ultrasound imaging setting, the quality of the image is impacted by the error between the backpropagating speed (usually assumed to be the speed of water) and the effective sound speed inside the medium to image. Therefore, in this work, we aim at constructing an estimator of the effective velocity in soft biological tissues. This is achieved by analyzing the dependence of the point spread function (PSF) with respect to the backpropagation speed. The PSF of an imaging system is the pattern produced on the image by a point-like object. When the theoretical PSF of a given system is known, the comparison with the pattern of a given image allows for an assessment of the quality of the image (blurring, aberration, presence of artifacts). We first prove that a point-like object can be used as a "guide star" to calculate the backpropagation speed inside a homogeneous medium. By studying the dependence of the pixel at the center of the focal spot with respect to the backpropagation speed, we show that the phase exhibits a jump when the backpropagation speed matches the sound speed in the medium.
However, in biological tissues, the backscattered wavefield does not come from isolated targets but from numerous unresolved randomly distributed scatterers. By focusing waves in the medium, we are able to recreate a "virtual guide star" and extract coherent data from the measurements to build an estimator of the effective sound speed in the complex medium, that exhibits the same phase jump. Finally, we perform a quantitative sensitivity analysis of our estimator and confront our result with experimental measurements.

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