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Uncertainty quantification in shear elastography

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Shear Wave Elastography is a non-invasive, quantitative ultrasound imaging technique that measures tissue stiffness by analyzing the speed of shear waves generated within the body. Harder tissues, such as fibrotic livers or tumors, cause waves to travel faster, while softer tissues allow slower propagation, providing objective diagnostic data. The measuring process and the measured data are affected by noise. When a nodule is identified, it is essential to determine its benign or malignant nature by quantifying the uncertainty due to the presence of noise and unknown factors. We propose an object-based Bayesian full-waveform inversion procedure with topological priors. Given the data, we are able to produce educated prior information on the number, location, and size of nodules by topological energy methods [1]. Parameterizing the nodules as star-shaped objects with a distinctive shear modulus, we introduce a low-dimensional inverse Bayesian formulation for the unknown random fields [1]. Given the observed data, a forward model of wave propagation and their uncertainties, we find the posterior probability of the parameters representing the geometry of the nodules and their shear moduli. Sampling this posterior distribution by Markov Chain Monte Carlo techniques we obtain ranked highest probability configurations (shear moduli and shapes) for the nodules. The uncertainty range about the highest probability shear moduli helps to decide about the nature of the nodules and the convenience of further studies. When the posterior distribution has a single mode, the process can be speeded up by a fast optimization scheme to calculate the maximum a posteriori estimate representing the most likely parameter values [1, 2]. We demonstrate the approach on synthetic two dimensional tests with smooth and irregular shapes. Very irregular shapes may require more complex parametrizations and different Bayesian approaches [3].

References

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