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MAPPING THE RELATIVE SHEAR MODULUS WITHIN BIOLOGICAL TISSUES FROM INTERNAL DISPLACEMENT FIELDS MEASURED IN QUASI-STATIC ULTRASOUND ELASTOGRAPHY

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Abstract

This presentation deals with relative shear modulus mapping within linear elastic and isotropic media, from the knowledge of displacement fields estimated in quasi-static ultrasound elastography (QSUE). QSUE mainly provides images of the internal displacements and strains that biological tissues experience under compression. Typically, the operator compresses the biological tissues with the probe while radiofrequency (RF) ultrasound images are acquired. With this technique, no boundary information is therefore available. Moreover, internal displacement fields are estimated from the acquired RF images, leading to 2D displacements, whereas the inverse problem is inherently a 3D one. In our recent work, mathematical developments for analyzing this inverse elasticity problem were introduced, as well as some initial results [1,2]. Here, to overcome the 2D/3D data problem, a plane stress-based approach is considered. The proposed method is based on the variational formulation of the equilibrium equations. This approach involves the use of test functions, chosen in this work to vanish at the domain boundary, because of the lack of information. Using a suitable finite element discretization technique leads to a finite dimensional homogeneous system of linear equations and the problem of reconstructing a relative shear modulus map is finally reduced to a null space identification problem of a large sparse matrix. With this method, only the displacement fields within the analyzed media need to be known beforehand. They are estimated using a method we previously developed for strain imaging [3].

Relative shear modulus mapping was assessed with plane stress and 3D numerical simulations, as well as data from phantom experiments (CIRS models 049 and 059). These different media consist of spherical inclusions embedded in homogeneous background materials. In all cases, the reconstructed maps allow a clear identification of the regions differing in stiffness, with inclusion-to-background modulus ratios (IBRs) that unambiguously reveal whether inclusions are stiffer or softer than the surrounding material. More specifically, for the plane stress simulations, resulting IBRs are very close to the theoretical values, whereas those obtained with the 3D simulations are, as expected, less accurate since the plane stress conditions are no longer satisfied. For the experimental data, a comparison with a clinical ultrasound scanner (Aixplorer, SuperSonic Imagine, France) was also conducted. Overall, for the phantom cases, the IBRs obtained with our approach are closer to the values given by the phantom manufacturer than the IBRs from the clinical system. Finally, results obtained with *in vivo* data of breast lesions will also be presented and discussed.

References

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