Ultrasonic Motion Tracking for Large Multi-Step Deformations

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Ultrasound elasticity imaging is a family of imaging modalities that uses tissue motion, tracked by ultrasound, to measure the elastic properties of tissue. One such property is the elastic nonlinearity, which quantifies the rate at which tissue gets stiffer as it is deformed. This nonlinearity may be able to help differentiate benign from malignant breast lesions, improving the screening and diagnosis of breast cancer.

Measuring the nonlinear properties of tissue requires large tissue deformations, which pose a challenge to standard motion tracking algorithms. Tracking large deformations in ultrasound requires dividing into multiple steps and accumulating the resulting sequence of displacements. The goal of this research has been to investigate and improve this multi-step accumulation process. On the scale of a whole displacement field, a comparison was made between tracking algorithms that follow individual speckle patches over time and algorithms that repeatedly measure displacement at the same spatial locations. Novel tracking algorithms were also developed that exploit temporal continuity to reduce tracking errors.

On the scale of the individual displacement estimate, the covariances between different steps in the accumulation sequence were analyzed and explained for the first time using simulations and phantom experiments. Linear estimators for total displacement have also been investigated, in which adding contributions from many overlapping strain steps may be able to improve the variance accumulated displacement estimates. Knowing the covariances between steps makes it possible to predict the success of possible estimators.

Finally, 3-D motion tracking in material coordinates has been implemented on phantom and ex vivo kidney samples undergoing large deformations. The experimental results are consistent with expectations from the simulation studies and will provide input data for reconstructions of elastic nonlinearity. Overall, the results of this work comprise a set of useful tools for understanding and improving large-deformation motion tracking.