NON-RIGID SOFT TISSUE TRACKING WITH THREE-DIMENSIONAL ULTRASOUND

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Aims: The primary focus of our research efforts is modeling the mechanical behavior of soft tissues for surgical simulation and virtual surgical environments. Our current tissue characterization approach combines traditional indentation testing with three-dimensional ultrasonic imaging. Estimates of complete deformation fields obtained through imaging are incorporated into an iterative finite-element modeling (FEM) scheme [1] to identify tissue-specific parameters of a physically-based nonlinear poro-viscoelastic constitutive law [2, 3]. Our preliminary work suggests that deformation fields obtained from traditional optical flow techniques [4, 5] suffer from prohibitively high levels of noise present in ultrasound images. To address this, we present a non-rigid motion tracking technique that combines local optical flow measurements with a deforming finite-element model to improve motion estimates in noisy datasets.

Methods: Characteristic force-displacement relationships are obtained from an indentation of porcine liver while imaging with 3D ultrasound (Philips SONOS 7500 Live 3D Echo, Philips Medical Systems, Andover, MA, USA), providing the ability to estimate the complete three-dimensional deformation field of the sample under indentation. Since good textural information is required for differential optical flow techniques, principal component analysis is used to quantify local textural content and provide confidence values associated with local motion estimates. A sparse set of local estimates of optical flow is computed in regions with high confidence values by a modified version of the Lucas-Kanade algorithm [5]. A finite-element model, reflecting tissue sample geometry, boundary conditions, and predetermined constitutive law parameters, is registered to the ultrasound volume and used to properly constrain and interpolate the sparse optical flow estimates. The resulting non-rigid tracking method relies on optical flow estimates in regions of significant texture, and on displacement estimates from FEM in regions without trackable features. In future work, we plan to implement the proposed approach in an iterative framework where the computed deformation fields are used to refine the estimates of the FEM constitutive parameters.

Results: We present preliminary results comparing deformation fields obtained from traditional optical flow methods of Horn and Schunck [4] and Lucas-Kanade [5] to those obtained from FEM-constrained optical flow. Tracking accuracy is evaluated on an indentation trial of porcine liver with embedded markers and synthetically generated motion scenes with varying levels of image noise. We demonstrate robustness of motion estimates in noisy datasets and reduced levels of multi-frame flow accumulation error.

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