Spatial-temporal-boundary regularization for cardiac motion tracking from noisy ultrasound images

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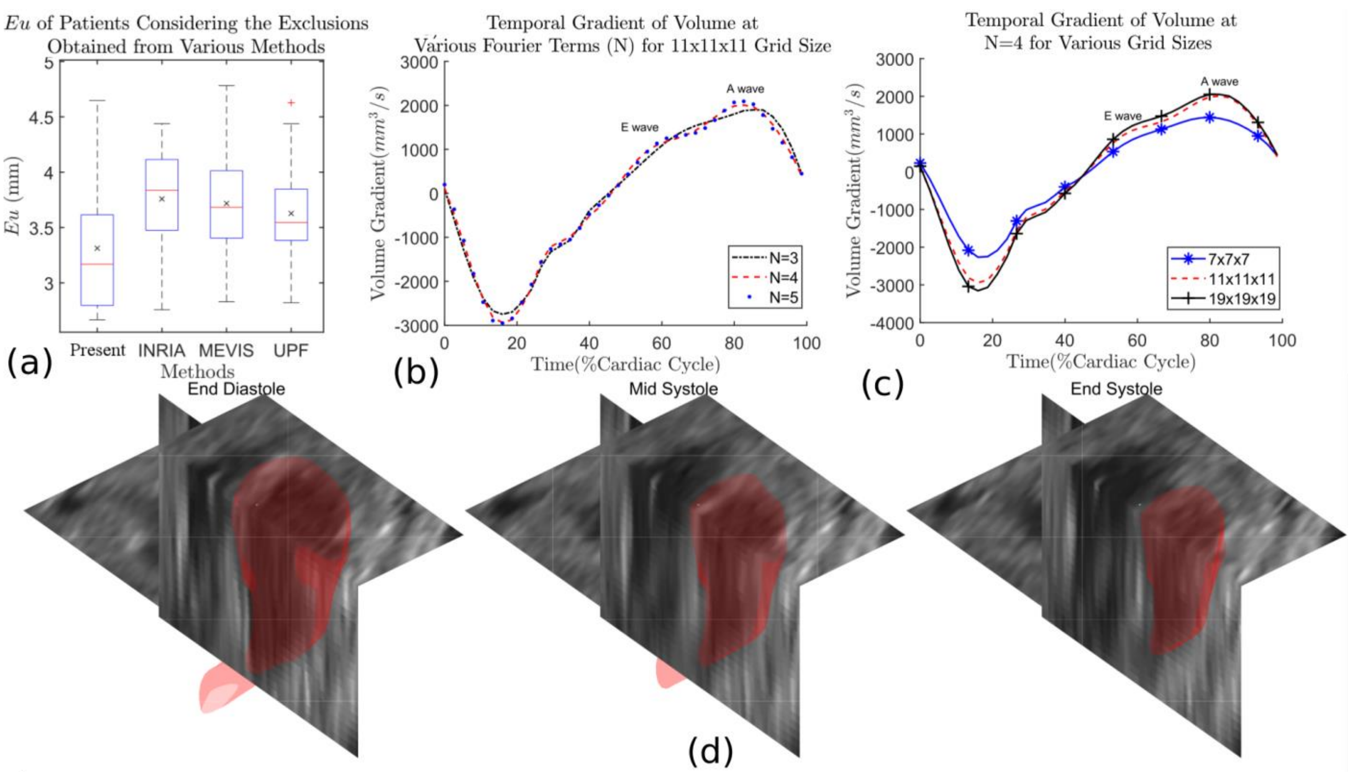
Accurate tracking of cardiac tissues from clinical scans is an important task to aid the evaluation of organ function, detect disease, and aid downstream biomechanics analysis. Motion tracking through image registration has worked for clean MRI images, but has limited accuracy in modalities such as ultrasound (US). Temporally, accumulated tracking errors scales in higher order than the based pairwise image registration errors. Spatially, due to regularization which prefers smoother displacement map, tracked cardiac boundaries often underestimates the stroke volume. In this study, we proposed a novel method for cardiac motion tracking on US images to address both of these problems. We curve-fitted a mathematical cyclic motion model to a series of non-rigid image registrations. Within our framework, emphasis could be placed on the images with the largest and smallest cardiac chamber volumes to preserve tracked stroke volumes. When applied the method to human adult left ventricle US as obtained from a recent cardiac motion challenge, our approach achieved 10% lower errors than other current techniques. The method was further applied to 4D human fetal cardiac US data, where we observed a good fit between out automatically tracked ventricular volume versus time data with manual segmentations at all time points. Our tracking method was also able to track E- and A-wave volume gradients. To demonstrate utility in biomechanics simulation, we demonstrated that the obtained cardiac wall displacements could be used as boundary condition for computational fluid dynamics (CFD) of the fetal RV. Consistent E and A-wave vortex rings were observed as expected and CFD velocities and stroke volumes matched clinically obtained data.



(a) Averaged Euclidean distance error. Gradient of volume over time curve for the fetal right ventricle at (a) considering different number of Fourier terms and (c) grid size. (d) Mesh motion of batch corrected data with additional vector inputs.