Accuracy Assessment of Time Delay Estimation in Ultrasound Elastography

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Background: Ultrasound elastography entails time-delay estimation (TDE) between ultrasound radio frequency (RF) data as the tissue undergoes deformation. TDE is utilized to calculate mechanical properties of tissue, which are often correlated with pathology [1]. The accuracy of TDE is usually measured by calculating the value of normalized cross correlation (NCC) at the estimated displacement [2]. NCC, however, can be very high at a displacement estimate with large error, a well-known problem in TDE referred to as peak-hopping [3].

Aims: TDE is challenging due to the signal decorrelation between the two ultrasound frames. Failure in TDE creates artifacts which can adversely affect the diagnosis or surgical operation. Accuracy assessment of TDE is important for several reasons: (i) To mask erroneous areas of the elasticity image, (ii) To obtain a weighted averaged of elasticity images, and (iii) To train sonographers to take high-quality elastograms.

Methods: Let I_1 and I_2 be pre-and post-compressed images [4]. In order to quantify accuracy of the displacement map, previous work only calculates NCC at the estimated time delay in I_2. In this work, we also calculate four neighboring NCC values around the estimated one to investigate the behavior of the similarity metric in the neighborhood of the estimated pixel. After obtaining these five NCC values for each pixel in I_1, a binary classifier (SVM) is used to evaluate the accuracy. Training the aforementioned model is done in two steps. First, according to the available ground truth for simulated data, we calculate five NCC values for all pixels in I_1 as a true set. Second, a random noise is added to the ground truth, and then five NCC values are calculated as a false set. Trained model with a large number of samples can be utilized to show accuracy map of the important regions in the strain image.

Results: Field II [4] and ABAQUS (Providence, RI) software are used for ultrasound simulation and for finite element simulation. The probe frequency is 7.27MHz, the sampling rate is 40MHz and the fractional bandwidth is 60%. These parameters are set to mimic commercial probes. Pre-and post-compressed images are of size 1041×250 and maximum axial and lateral displacements are 10 and 1 samples in displacement field. The proposed method has been applied to the aforementioned data wherein the number of training and validation samples are 62690 and 6269, respectively. Classification accuracy for using one NCC is 71.8% and using 5 NCC values is 84.56 %. Accuracy map of the tumor region using 1 NCC and 5 NCC values has been shown below for NP (Negative Prediction) class. NP class addresses the output of the classifier that must be recognized as negative set. Failed pixels are shown in Figs c and d in black. It is clear from this image that the number of failed pixels using 5 NCC values is much less than using 1 NCC value in Figs c and d. These results show that the proposed method substantially outperforms traditional techniques. We have also validated our method on phantom and in-vivo data.

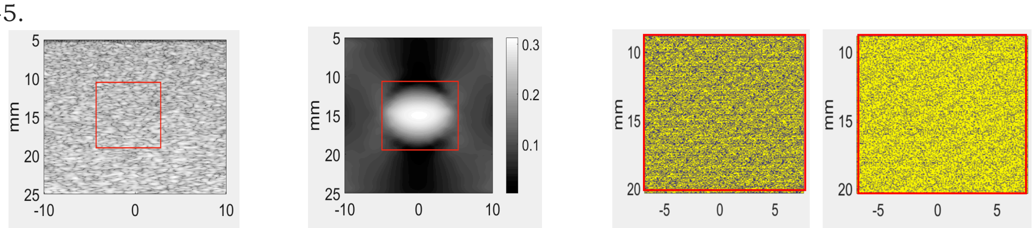
References:

[1] Ophir, J., et al. " Elastography: ultrasonic estimation and imaging of the elastic properties of tissues." Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine 213.3 (1999): 203-233.

[2] Viola, Francesco, and William F. Walker. "A comparison of the performance of time-delay estimators in medical ultrasound." *IEEE transactions on ultrasonics, ferroelectrics, and frequency control* 50.4 (2003): 392-401.

[3] Walker, William F., and Gregg E. Trahey. "A fundamental limit on delay estimation using partially correlated speckle signals." *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control* 42.2 (1995): 301-308.

[4] Rivaz, Hassan, et al. "Real-time regularized ultrasound elastography." *IEEE transactions on medical imaging* 30.4 (2011): 928-945.



Left to right (a-b-c-d) : (a) B-mode image, (b) Strain image, (c) Accuracy map using 1 NCC value for NP class, (d) Accuracy map using 5 NCC values for NP class. Black pixels in figures c and d show failed pixels in the area within the red square.