Ultrasound shear strain imaging for breast cancer classification

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At the University of Wisconsin-Madison

2013

Early detection of breast cancer can significantly reduce breast cancer mortality and morbidity. Pathological differences between benign and malignant masses include the stiffness contrast, nonlinear stiffness variations and changes in breast mass boundaries evoked by desmoplastic scirrhous reactions. Ultrasound as a low cost and safe imaging modality has become the primary adjunct to mammography for screening. Ultrasound elasticity imaging can differentiate breast masses based on different mechanical and acoustic properties.

The goal of this dissertation is to evaluate features (normalized axial and full shear strain area, namely NASSA and NFSSA) derived from shear strain imaging for breast mass differentiation. Finite element simulation, tissue-mimicking (TM) phantom experiments, and *in-vivo* studies, are utilized to evaluate new algorithms and perform statistical analysis.

A new two-dimensional (2D) parallelogram kernel motion tracking algorithm was developed in this dissertation to estimate displacement vectors for normal and shear strain imaging, utilizing beam-steered ultrasound radiofrequency data. Quantitative analysis based on the elastographic signal-to-noise (*SNRe*) and contrast-to-noise (*CNRe*), was utilized to demonstrate the statistical significance of the results obtained from TM uniformly elastic and ellipsoidal inclusion phantoms respectively. Our results demonstrate that our 2D deformation tracking significantly outperforms the currently utilized one-dimensional (1D) algorithm for beam-steered data.

Classification results obtained using radiofrequency data sets on 123 patients (benign: 65, malignant: 58) acquired at four hospitals equipped with two different ultrasound systems, were utilized to demonstrate the feasibility of using these normalized features extracted from the axial strain and axial-shear strain images for breast cancer diagnosis. Scatter plots of the NASSA feature shows that most of the malignant masses exhibit a NASSA value larger than 1.2, while for benign masses, it is lower than 1.2. The corresponding area under (AUC) the receiver operating characteristic (ROC) curve of 0.9 demonstrates the potential of using the NASSA feature for breast mass classification. Integrating the NASSA feature with the previously proposed features, namely the 'size ratio' and the 'stiffness contrast', further improves the classification performance, achieving an AUC of 0.93. These results demonstrate the potential of elasticity based imaging features for breast mass differentiation and classification.