Ultrasound Speckle Reduction using Coded Excitation, Frequency Compounding, and Post-processing Despeckling Filters

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Background, Motivation and Objective

In ultrasonic imaging, the detection of small or low-contrast lesions could be masked because of speckle. A speckle reduction technique known as REC-FC, which uses coded excitation, pulse compression, and frequency compounding, was recently developed. In REC-FC, the speckle is reduced and the contrast is improved but at the expense of a reduction in axial resolution. However, by compounding various REC-FC images made from various subband widths the tradeoff between axial resolution and contrast enhancement was extended. In this study, the speckle in the enhanced REC-FC (eREC-FC) images could be further reduced by applying post-processing despeckling filters, consequently improving image contrast while maintaining key features in the ultrasound image.

Statement of Contribution/Methods

Simulations and experimental measurements were conducted with a single-element transducer (f/2.66) having a center frequency of 2.25 MHz and a -3-dB bandwidth of 50%. The -3-dB bandwidth was doubled with REC. In simulations, 30 tissue-mimicking phantoms of hyperechoic (+6-dB) targets were imaged. In experimental measurements, a hyperechoic (+6-dB) target from an ATS 539 tissue-mimicking phantom was imaged. The post-processing despeckling filters evaluated were: median, homogeneous mask area (HMA), Lee, geometric, and speckle reducing anisotropic diffusion (SRAD). The first three filters make use of a moving, overlapping window (size n x n, for odd n), and the last two are iterative techniques. To assess the performance of the despeckling filters, image quality metrics, such as contrast-to-noise ratio (CNR), and comparative signal-to-noise ratio (cSNR) were evaluated and compared to images generated using conventional pulsing (CP) excitation. CNR determines the contrast between two regions, while the cSNR determines the relative decrease in speckle.

Results

In simulations, the CNR for eREC-FC exhibited an average improvement of 150% over CP was achieved. After applying the post processing filters, the CNR increased by an average of 388%, 400%, 413%, 350%, and 563% for median, HMA, Lee, geometric, and SRAD, respectively, compared to CP. For cSNR, a change of -2%, -3%, -1%, +10%, +70% was achieved for median, HMA, Lee, geometric, and SRAD, respectively, compared to eREC-FC. In experiments, the CNR for eREC-FC improved by 187% over CP. After applying the post processing filters, the CNR increased by 312%, 350%, 361%, 286%, and 234% for median, HMA, Lee, geometric, and SRAD, respectively, compared to CP. For cSNR, a change of -2%, -2%, -1%, +15%, +110% was achieved for median, HMA, Lee, geometric, and SRAD, respectively, compared to eREC-FC.

Discussion and Conclusion

Simulation and experimental results suggest that applying post processing despeckling filters to eREC-FC images resulted in significant improvements in contrast and reduction of speckle when compared to CP. eREC-FC combined with SRAD resulted in the best overall performance using the aforementioned metrics.