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High-sensitivity shear wave elasticity imaging using phase-based motion magnification

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1. Introduction

Shear wave elasticity imaging (SWEI) has the ability to assess the elastic properties of tissue non-invasively and quantitatively[1)]. The majority of SWEI methods apply an acoustic radiation force to generate shear waves and then measure shear wave velocities (SWVs) that are a function of shear (or Young's) modulus[2)].

To estimate the SWVs, the propagation of the shear waves needs to be visualized. Imaging of shear wave waves relies on measuring motion of particles along the axis perpendicular to the direction of shear wave progagation. Typically, ultrafast ultrasound imaging capturing the particle motion and correlation-based methods finding this motion-induced particle displacements or axial velocities of particles are used[3, 4)]. These displacements effectively represent the shear waves, but they are typically subtle (usually, tens of microns)and rapidly attenuate[5)].

This paper investigated a method to intensifying the particle motion to improve the displacement sensitivity needed for high quality SWEI. We have adopted a phase-based motion magnification originally developed for enhancing subtle motion in videos[6)]. To verify our approach, an elasiticy phantom was imaged and we compare means and standard deviations (STDs) of the SWVs processed with and without motion magnification under the presence of various levels of noise.

2. Materials and Methods

2.1 Phase-based motion magnification

Recently, phase-based motion magnification that effectively amplifies subtle movements while suppressing noise amplification was proposed[6)]. The approach is based on the Fourier shift theorem; local motion (or translation) in space-time signals corresponds to phase variation in frequency domain signals. While phase is manipulated to amplify the motion, noise signals are merely translated rather amplified.

In this study, we applied phased-based motion magnification to post-beamformed ultrasound data to amplify motion of imaged material. Then, for comparison, we reconstructed SWVs using both the motion-magnified and original data sets. To create shear waves, we used a single push pulse (as shown in Fig. 1 (a)) and tracked the shear wave propagation with ultrafast imaging and auto-correlation. Then we reconstructed SWVs using cross-correlation.

2.3 Experimental set-up

We imaged an elasticity phantom (Model 049, CIRS Inc., Norfolk, VA) using a research ultrasound system (Vantage-256, Verasonics Inc., Redmond, WA) with a L7-4 linear array transducer. A 4.0-MHz frequency push pulse of a 200-μs

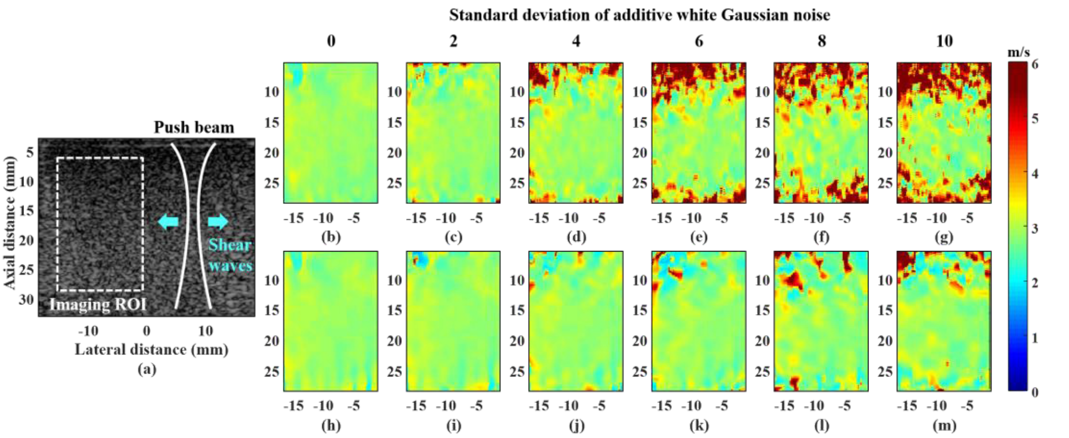

Fig. 1 B-scan ultrasound image and reconstructed SWV maps of the homogeneous material under various levels of noise. (b)-(g) SWV maps processed without motion magnification. (h)-(m) SWV maps processed with motion magnification by a factor of 20.

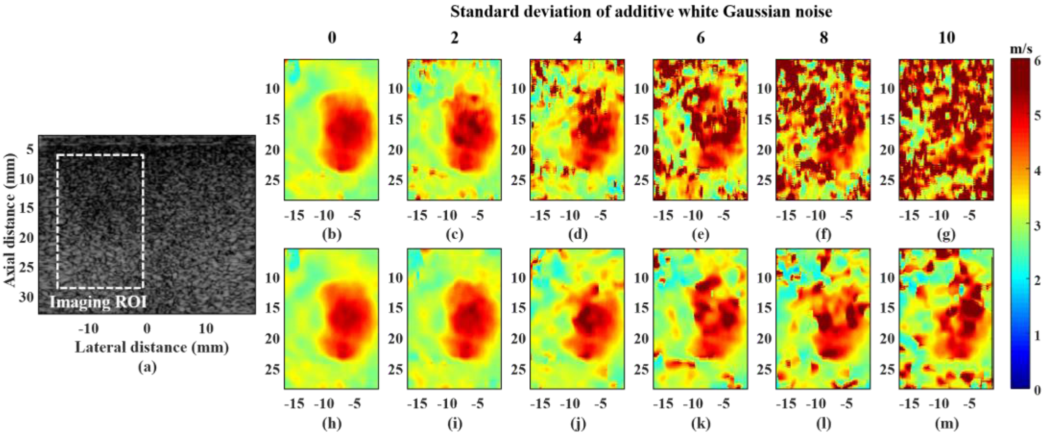

Fig. 2 B-scan ultrasound image and reconstructed SWV maps of a phantom containing rounded target within homogeneous background. Various levels of noise were added prior to reconstruction. (b)-(g) SWV maps processed without motion magnification. (h)-(m) SWV maps processed with motion magnification by a factor of 20.

duration was focused at a 20-mm depth. A pulse repetition frequency of plane waves for ultrafast imaging was 10 kHz. The spatial compounding using three angles (−4°, 0°, and 4°) of the plane wave imaging was applied. For motion magnification, the quarter-octave steerable pyramid was used. Motion amplification factor was set to 20. The lower and upper passband frequencies of the temporal band-pass filter were 100 Hz and 1,000 Hz, respectively.

3. Results and Discussion

The results of the SWV estimation with and without motion amplification are shown in Fig. 1 and Fig. 2 for the homogeneous region of interest and homogeneous bachground containing a signle rounded stiff inclusion, respectively. Various levels of noise were applied prior to SWV estimation. Images with motion magnification (second rows in Fig. 1 and Fig. 2) consistently indicate that our approach is robust and more sensitive compared to conventional SWEI. Also, in Fig. 3, the SWVs reconstructed using motion amplification approach are more accurate and closely represent the nominal values. As STD of noise increases, the STDs of the SWVs also increase. However, if motion magnification applied, lesser increase in STDs is observed.

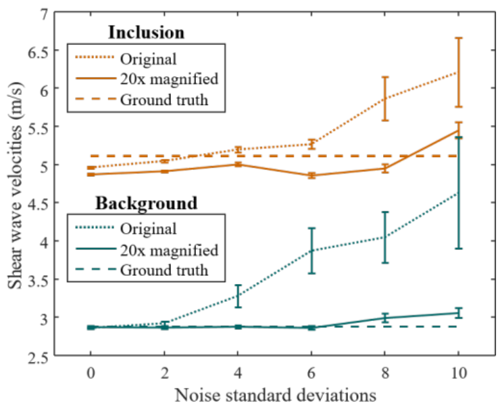

Fig. 3 Mean and STDs of SWVs in the inclusion and the background.

4. Conclusion

We introduced the SWEI method based on phase-based motion magnification. We verified our approach in the tissue-mimicking phantom and showed that motion magnification processing could improve the quality of SWV images.

Acknowledgment

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