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Singular Value Decomposition-based HIFU Interference Filtering for Real-time Harmonic Imaging-guided Therapy

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Abstract— **High-intensity focused ultrasound (HIFU) is an emerging tool for effective thermal ablation of tissue. However, real-time monitoring of HIFU treatment is challenging, as HIFU application causes strong interference for imaging. Thus, this paper introduces singular value decomposition-based filtering capable of removing the HIFU interference from harmonic images without undesirable spectral distortion. The results experimentally validated with a custom-made phantom indicate that our approach eliminates HIFU-induced artifacts effectively, which is essential for real-time monitoring of therapeutic process.**

I. Introduction

Over the past decade, high-intensity focused ultrasound (HIFU) has shown promising outcomes as a non-ionizing, non-invasive ablation modality. HIFU can be also guided by either ultrasound or magnetic resonance imaging, allowing for monitoring of on-going treatment [1]. For prompt control of HIFU dosage and ablating location, ultrasound guidance is preferred, but HIFU sonification prevents simultaneous imaging because of severe mutual interference. To address this challenge, this paper suggests singular value decomposition (SVD)-based filtering that effectively preserves ultrasound signals for harmonic imaging while suppressing unwanted HIFU-induced interference signals.

II. Methods

Figure 1 shows the overall procedure of our SVD-based filtering approach [2]. Each scanline of ultrasound data is first rearranged to compose a Hankel matrix and then decomposed as SVD components. From each SVD component, singular values corresponding to HIFU frequency and noise are estimated and removed before reconstruction of ultrasound image.

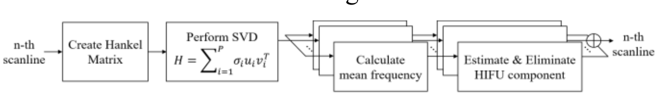

Figure 1. Flow chart of a SVD-based HIFU interference filtering method.

For experimental validation, we imaged a custom-made polyacrylamide phantom containing pin and cyst targets using a Verasonics research platform (Vantage 128) with a C5-2v probe transmitting at 2 MHz, while applying HIFU beams with a single-element HIFU transducer at 1.6 MHz (H-230, Sonic Concepts Inc.).

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III. Results

Fig. 2 shows ultrasound images and associated spectra obtained under HIFU application. Because of HIFU interference, any structural information from the phantom cannot be identified (Fig. 2a). However, SVD-based filtering successfully removes the interference, and thus, the pin and cyst targets become clearly observable. In addition, harmonic imaging results (Fig. 2c) showed improved resolution and contrast over fundamental results (Fig. 2b).

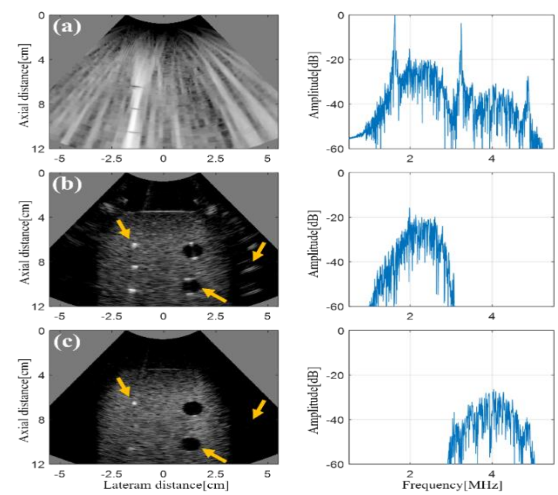

Figure 2. Ultrasound images and assocated frequency spectra obtained during HIFU application. (a) Original with interferce, (b) interference-free fundamental image, and (c) interference-free harmonic image.

IV. Discussion & Conclusion

We have suggested SVD-based filtering to support real-time interference-free guidance of HIFU treatment. Our imaging results indicate that the approach effectively removes the interference while preserving the image quality.

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