Ultrasound Angiography with Tissue Echoes Filtering and Adaptive Beamforming

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Background, Motivation and Objective

Ultrasound angiography based on delay-and-sum (DAS) beamforming has enabled mapping of blood flow in soft tissues, e.g., myocardium, brain, and kidney, but its resolution and contrast were suboptimal due to inherent limitations of the DAS beamformer. Adaptive beamformers (data-dependent) show improved resolutions and contrast for B-mode at the expense of increased speckle variations, which degrade the clutter filtering performance. This study thus aims at circumventing the drawback of adaptive beamforming to significantly improve the quality of contrast-agent-free ultrasound angiography.

Statement of Contribution/Methods

We hereby propose a new scheme with tissue echoes filtering (TEF) and adaptive beamforming for ultrasound angiography. The new TEF strategy is different from the conventional clutter filtering scheme in that we directly apply a linear spatiotemporal filter (i.e., singular value decomposition (SVD)) to pre-beamformed signals, instead of beamformed ones, to extract blood echoes and remove tissue echoes. The subsequent adaptive beamforming step is performed on the extracted blood echoes, instead of the original received echoes. Such "filtering followed by beamforming" strategy is the key to achieving the full strength of adaptive beamforming.

In vivo open-chest adult farm pig's heart (6 months, 35 kg) was scanned using a Verasonics® Vantage system with an L7-4 probe (center frequency 5.2 MHz, four plane waves (-7 degrees to 7degrees) at 1000 compounded frame rate). Blood flow was mapped using power Doppler of 50 beamformed images at the early diastole. Both DAS and adaptive beamformers, such as minimum variance (MV), filtered delay multiply and sum (F-DMAS) and cross-coherence factor (CCF), were performed for comparison.

Results/Discussion

Ultrasound angiography with adaptive beamforming (MV, F-DMAS, CCF) followed by clutter filtering degraded expectedly the blood vessel image quality (Fig. 1 B_1-D_1) because of the increased speckle variations. In contrast, our proposed "TEF followed by adaptive beamforming" enhanced the delineation of blood vessels in the myocardium (Fig. 1 B_2-D_2), with improved contrast ratios (black box in Fig.1A_2) being +7.2 dB by MV, +6.2 dB (F-DMAS), and +15.1dB (CCF), compared to DAS. Note that the proposed TEF made no difference in the case of DAS beamformer (Fig. 1A_1, A_2) because of their intrinsic linearity.

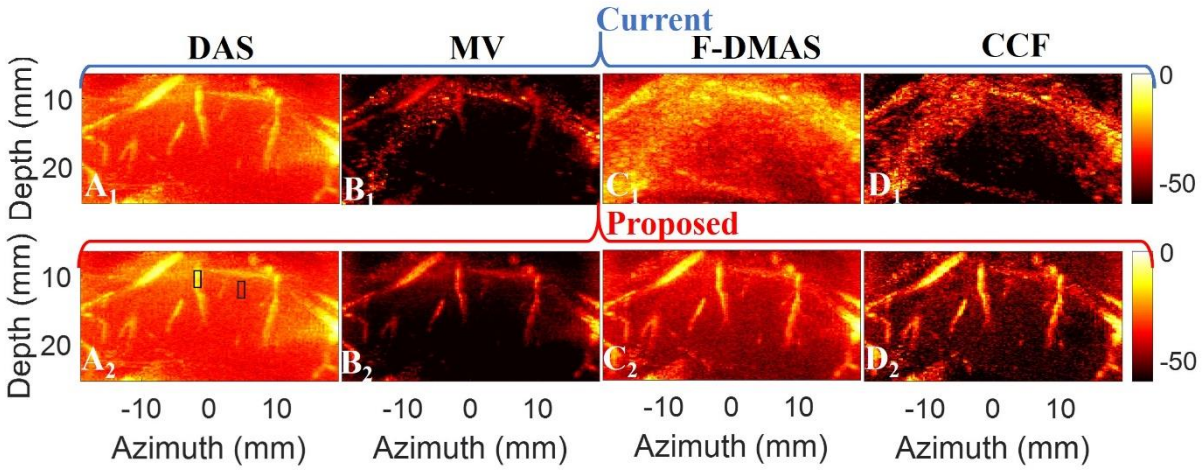

Fig.1. *In vivo* myocardial blood flow at early diastole without contrast agents. A_1, B_1, C_1, and D_1: ultrasound angiography images obtained by existing methods with clutter filtering of beamformed data from DAS, MV, F-DMAS, and CCF, A_2, B_2, C_2, and D_2: ultrasound angiography images via our proposed scheme with tissue echoes filtering (TEF) of pre-beamformed data. Note that DAS denotes Delay-and-Sum, MV denotes Minimum Variance, F-DMAS is Filtered Delay Multiply and Sum, and CCF refers to Cross-coherence Factor.