Dictionary Learning for Sparse Regularization Reconstruction of Ultrafast Ultrasound Image

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Background, Motivation and Objective

Sparse regularization (SR) can reconstruct high quality image from plane wave (PW) transmission with high memory footprint and heavy computational load. Previously, we established a measurement model in the form of a sparse matrix to reduce the memory consumption. However, as a commonly used sparsifying model in SR, concatenation of multi-level wavelet transforms (WT) cannot preserve the speckle density well and increase the computational complexity. In this work, we proposed to replace the WT with learned dictionary, to further improve the image quality and reduce the computational complexity.

Statement of Contribution/Methods

A sparse measurement model (i.e., ϕ) was established in time domain for acquired echo signals (i.e., y) with single PW transmission. With a sparsifying model (i.e., φ), the desired images (i.e., x) can be reconstructed with iterative algorithms [Fig. (a)]. In the training process of the proposed dictionary-based SR reconstruction, the images were reconstructed with WT as sparsifying model (step 1 in Fig. b) and then organized as the training data of K-SVD algorithm to learn a sparse representation dictionary (step 2). The learned dictionary can be used as the sparsifying model (step 3) for image reconstruction.

Field II simulations and *in vivo* experiments were performed to evaluate the performance of the proposed method. Cystic phantoms were simulated to quantify the contrast-to-noise ratio (CNR). The carotid artery and biceps (healthy volunteer) were scanned with a Verasonics Vantage system equipped with an L12-5 probe (f0 = 7.5 MHz) by multi-angle PW imaging. The carotid artery in the cross section and biceps data were used for training of dictionary, and the reconstruction quality was evaluated on the carotid images in the longitudinal section.

Results/Discussion

Table I shows that the proposed method can achieve higher CNR than WT based SR reconstruction (both with single PW transmission) and PW compounding with 15 PW transmissions in simulations. Fig. (c) shows that the proposed method obtains more continuous vessel structure (yellow arrows) and higher speckle density (red arrows) in the carotid artery. The higher image quality is probably because the learned dictionary is an overcomplete model and optimized for ultrasound signals. The optimization process of the proposed method consists of matrix multiplication only, and therefore the algorithm can be implemented on GPU with acceptable memory consumption for great acceleration.

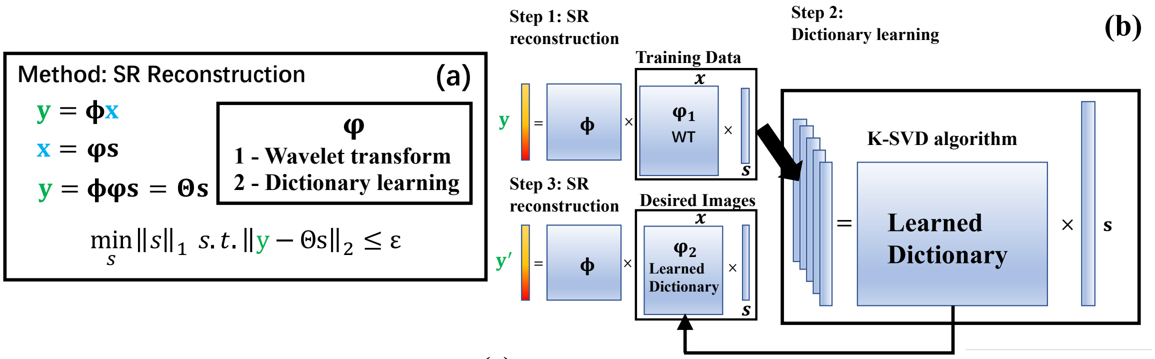

Table I. CNR [dB] comparison

Recon. Method / No. TXs	DAS	SR with dictionary	SR with WT
1	9.38	15.95	13.26
5	10.83	-	-
9	11.52	-	-
15	13.22	-	-