Abstract 391

Adaptive Wavelet Thresholding for Profile-Encoding Reconstruction of Balanced Steady-State Free Precession Acquisitions

Session Type: Scientific Session

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Purpose / Introduction

A powerful strategy to suppress banding artifacts while maintaining scan efficiency in balanced steady-state free precession (bSSFP) imaging is to accelerate multiple phase-cycled acquisitions [1,2]. We have recently proposed a profile-encoding framework (PE-SSFP) where undersampled bSSFP acquisitions are jointly reconstructed across phase-cycles to recover unacquired data. The PE method was shown to achieve superior image quality compared to conventional parallel imaging and compressed sensing reconstructions [2]. PE enforces sparsity by soft-thresholding of the entire wavelet tree via a single, manually determined threshold. Here we propose an improved method where the optimal wavelet threshold for each sub-band is automatically determined from the data. The proposed method reduces reconstruction artifacts while preserving detailed tissue depiction in bSSFP images.

Subjects and Methods

In multiple-acquisition bSSFP imaging, several images with different phase-cycling increments are acquired. Because the spatial locations of the banding artifacts differ across phase cycles, individual images can be combined to suppress artifacts. In a recent study [2], we developed a PE reconstruction that linearly synthesizes unacquired data in accelerated phase-cycled acquisitions, and leverages joint sparsity and total variation penalties to suppress aliasing and noise. As input, the PE method requires manual specification of a single wavelet threshold that is enforced on the entire wavelet tree. Here, we propose to automatically determine appropriate thresholds for each wavelet subband by the PES-L1 method, which enforces sparsity by projecting wavelet coefficients onto the epigraph set of the L1-ball. This epigraph set represents the family of L1-balls with the maximum size equal to the L1-norm of the wavelet coefficients prior to projection. A unique projection that yields wavelet coefficients closest to the L1-ball of size 0 is then determined [3,4].

The proposed method was demonstrated on brain phantom and in vivo brain acquisitions. PE reconstructions were obtained using PES-L1, and conventional soft-thresholding (with matched average threshold). Image quality was assessed via the peak signal-to-noise ratio (PSNR).

Results

Figure 1 shows reconstructions of 4- and 8-fold phantom acquisitions; Figure 2 shows reconstructions of 8-fold accelerated in-vivo acquisitions. The proposed method achieves more detailed tissue depiction compared to conventional soft-thresholding. This assessment is supported by PSNR measurements listed in Table 1.

fig1_rgb-01.jpg

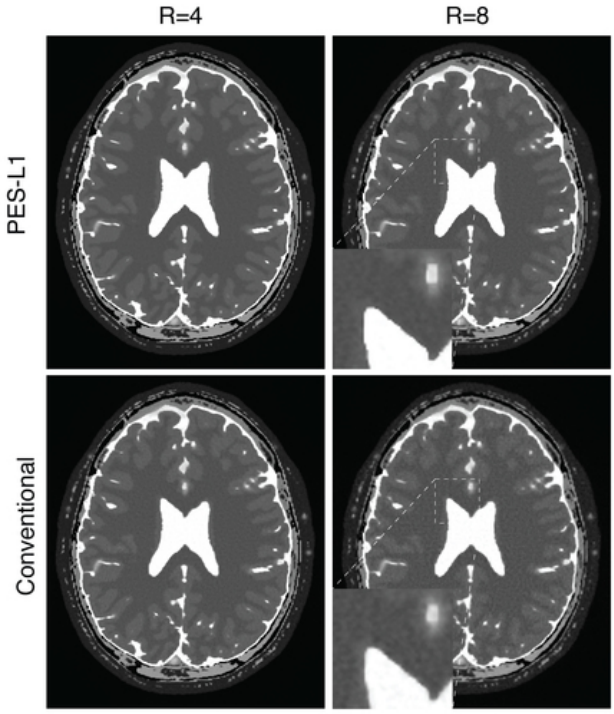

Figure 1. ***Reconstructions for the brain phantom.*** Phase-cycled bSSFP acquisitions were simulated for N=4,8, α=45, TR/TE = 5/2.5ms, and a field map of 0 $\pm$ 0.62Hz (mean $\pm$ std). PE reconstructions with conventional and PES-L1 thresholding are shown for R=4, 8 (variable-density random sampling). The subband thresholds determined via PES-L1 were averaged and used in the conventional method. PES-L1 achieves improved noise suppression and visually sharper tissue depiction.

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fig2_rgb-01.jpg

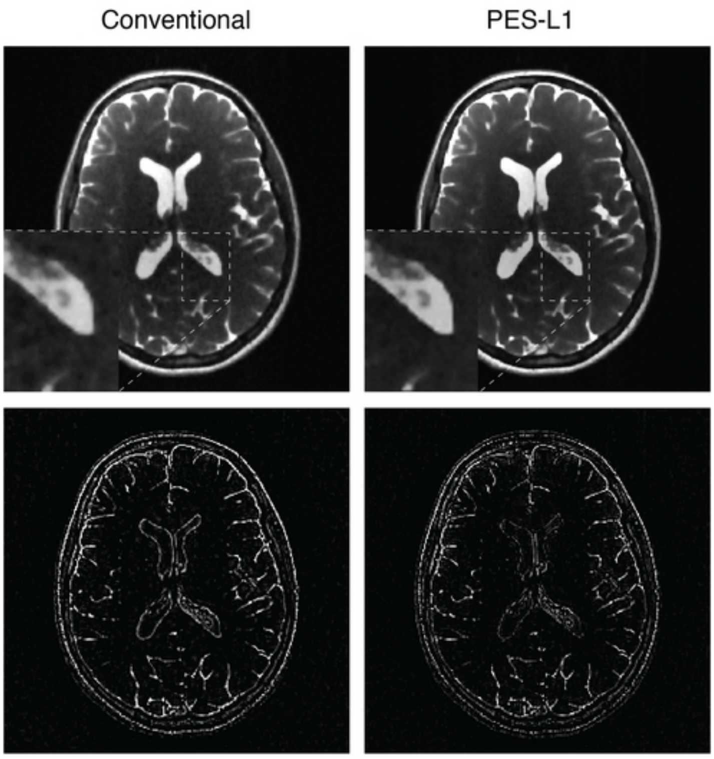

Figure 2. ***PE reconstructions for the in-vivo brain.*** Eight phase-cycled acquisitions were performed. Images from conventional and PES-L1 thresholding are shown for R=8 ***(top row)***. The subband thresholds determined via PES-L1 were averaged and used in the conventional method. Error images with respect to a fully-sampled reference acquisition are also shown ***(bottom row)***. PES-L1 achieves improved noise suppression and visually sharper tissue depiction.

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table1_rgb-01.jpg

		Phantom	In vivo
PES-L1	R=4	34.5±0.7	35.7±0.7
	R=8	27.9±0.6	34.0±0.2
Conventional	R=4	29.9±0.5	34.1±0.6
	R=8	25.7±0.6	32.3±0.1

Table 1. ***PSNR measurements on phantom and in vivo reconstructions.*** PSNR for conventional and PES-L1 thresholding are listed as mean±std. across five axial slices. PES-L1 significantly improves image quality in both datasets across all acceleration factors.

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Discussion / Conclusion

The proposed method enforces sparsity via an adaptive threshold in each wavelet subband to improve sensitivity for sparse recovery. The thresholds are determined from the acquired data without supervision. As a result, the proposed method reduces noise/aliasing artifacts and improves spatial resolution compared to reconstructions based on conventional wavelet thresholding.

References

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