Variable-Density Parallel Imaging with Partially Localized Coil Sensitivities

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Introduction: Many parallel imaging methods reliably process non-Cartesian data [1-3], but are computationally intensive. In contrast, PILS [4] delivers fast reconstructions, but yields residual aliasing for variable-density (VD) acquisitions. A modified k-space approach that addresses this problem has recently been introduced with preliminary results [5]. We propose a considerably faster image-domain method that reduces the artifacts in coil images with variable-FOV gridding, and assembles the final image with an optimal linear combination. This method is especially suitable for non-Cartesian data, as demonstrated by in vivo comparisons with SENSE [2] at acceleration factors (R) up to 4.5.

Methods: To suppress aliasing artifacts while optimally utilizing the data in VD acquisitions, we should use the densely sampled low-spatial-frequencies to reconstruct a larger FOV_{low}, and constrain high frequencies to a smaller FOV_{high} (Fig. 1). Following regular gridding reconstruction, the k-space data are segmented based on the sampling densities (e.g., into annuli for VD spirals), and the images are apodized to limit FOV (determined by the mean density of each segment). These coil images are then combined with optimal weights obtained from data-driven sensitivity estimates [6]. To prevent blurring, the weights are computed separately for low and high frequency images, $\mathbf{S_i^L}$ and $\mathbf{S_i^H}$. Assuming $\mathbf{C_i}$ denotes the sensitivity of the $\mathbf{i}^{th}$ coil, and $\mathbf{I_i^{L,H} = \{1 \text{ if } S_i^{L,H} \neq 0;\ 0 \text{ otherwise}\}}$, the final image is: $\mathbf{P} = \{(\sum \mathbf{S_i^L C_i^*})/\sqrt{(\sum \mathbf{I_i^L}|\mathbf{C_i}|^2)}\} + \{(\sum \mathbf{S_i^H C_i^*})/\sqrt{(\sum \mathbf{I_i^H}|\mathbf{C_i}|^2)}\}$.

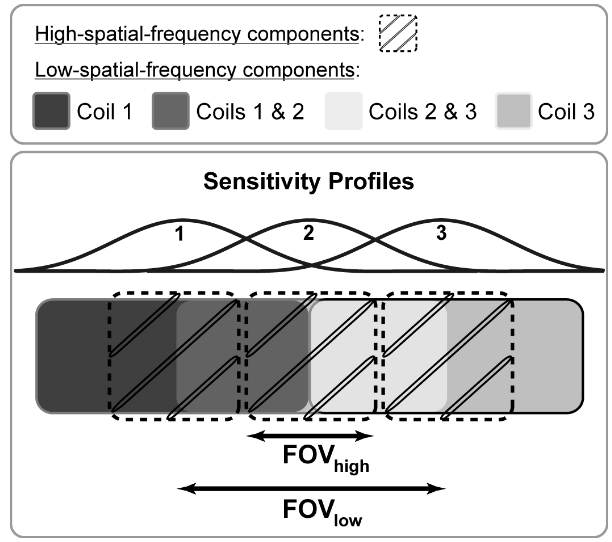

Figure 1. Reconstruction FOVs of individual coils in an example 1-D array for low- and high-spatial-frequencies. Different colors are used to mark overlapping low-spatial-frequency images from neighboring coils.

Results: Fig.2 shows VD-spiral images from an 8-element array, at R=2.3 and 4.5. The proposed method (5 annuli) suppresses the residual artifacts in PILS images. While SENSE can suffer from increased noise due to poor conditioning of the encoding matrix at higher R, the variable-FOV method is relatively immune to this effect and achieves a 10-fold reduction in processing time. Inaccurate sensitivity estimates create residual aliasing in SENSE, whereas they may cause localized under/over-weighting of low-frequency data in variable-FOV images. However, such artifacts were not apparent.

Conclusion: The proposed method provides fast, reduced-artifact, and high-SNR auto-calibrated reconstructions for variable-density acquisitions, enabling higher acceleration factors. It could be a simple and efficient alternative, particularly for non-Cartesian sampling.

References:
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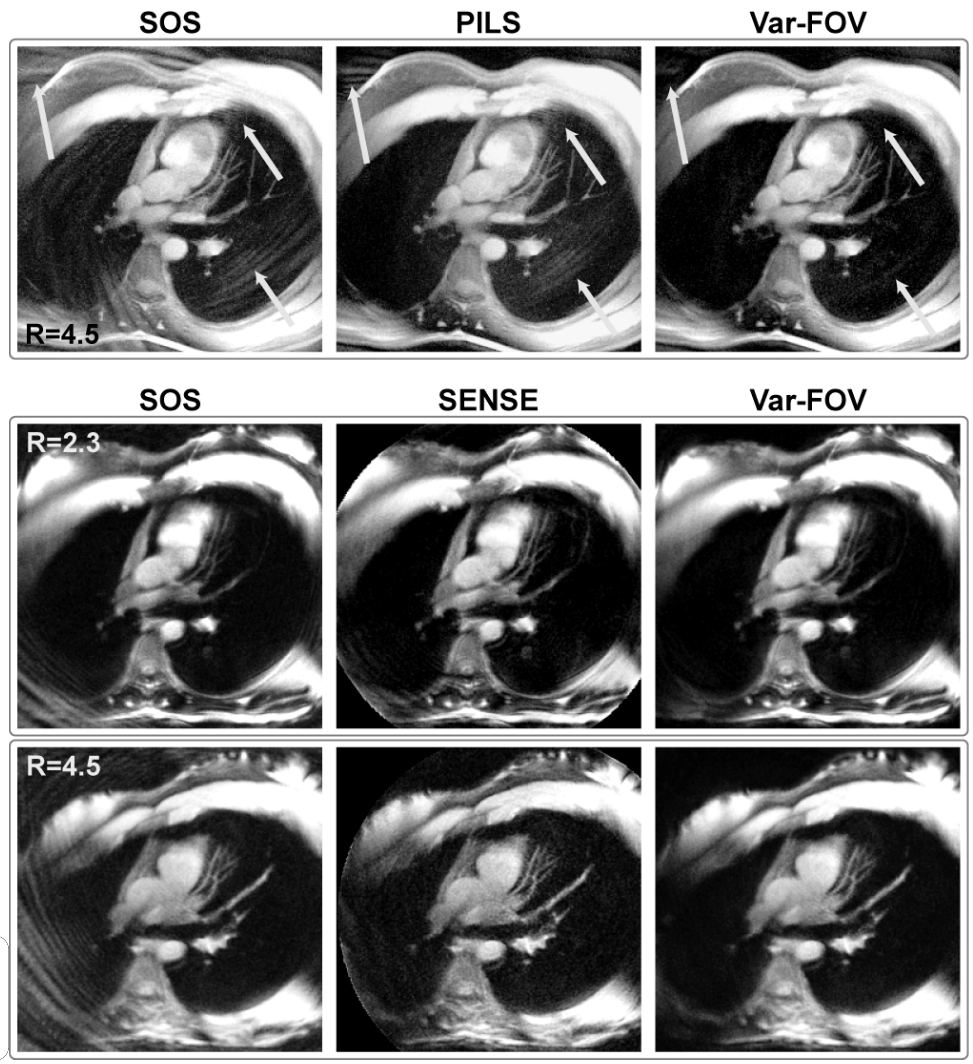

Figure 2. Variable-FOV images compared to PILS at R=4.5, and SENSE at R=2.3, 4.5. Arrows point to residual artifacts in PILS. SOS images are also shown.