A Fast Optimal Method for Coil Sensitivity Estimation and Adaptive Coil Combination for Complex Images

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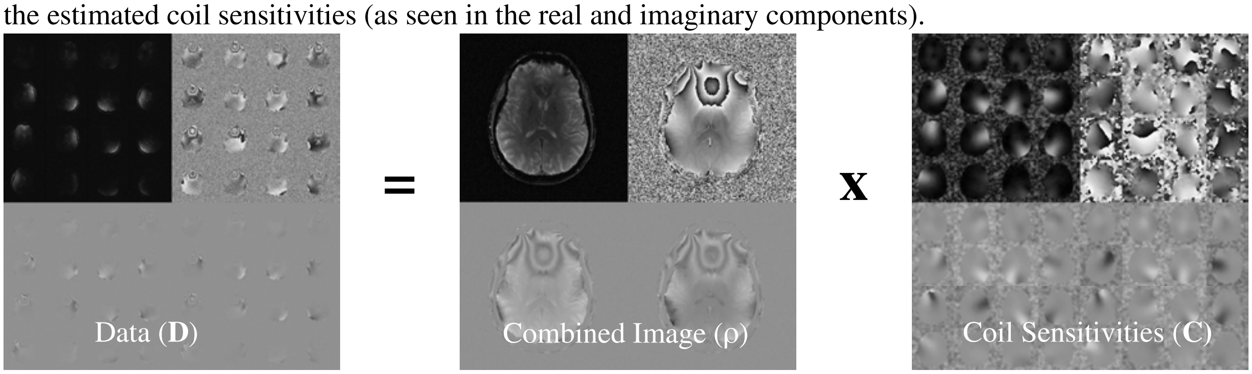
Target audience: Clinicians/researchers using coil arrays for phase sensitive imaging

Purpose: A SNR optimal method for coil sensitivity estimation and adaptive combination. The proposed method enforces smoothness in both the magnitude and phase of the estimated coil sensitivities. It has a very fast implementation and can be easily incorporated into a reconstruction pipeline for the calibration step of parallel imaging reconstruction, and in applications that require complex valued images such as susceptibility weighted imaging, complex interpolation, complex motion correction, and referenceless thermometry.

Theory: Adaptive phase array combiners (1) estimate the relative phase difference between the coil sensitivities, because the measured data (**D**) is the product of the object (ρ) and the coils sensitivities (**C**); multiplying ρ and dividing C by an arbitrary smooth function matches **D** equally well. Therefore, the absolute phase of the combined signal cannot be determined, and it is necessary to choose a phase reference. Typically, one coil is chosen arbitrarily as a phase reference. Unfortunately, in regions where the reference coil has low SNR, the reference phase can be noisy, and the phase of the estimated relative coil sensitivities is no longer smooth. Recently, Inati et al (3) proposed a variant of the adaptive matched filter based on finding the first singular vector of the data in a local region around each pixel. They chose to put all of the common phase into **C** and showed that it is possible to estimate optimal **C** with smooth magnitude and phase, but at the expense of high pass filtering the phase of ρ. In this work we make two significant improvements to this method: 1) we make the phase of **C** as smooth as possible and put as much of the phase as possible into ρ, and 2) we develop a very fast procedure using sums and convolutions.

Methods: Data were acquired from a human volunteer on a Siemens 3T Skyra scanner using the vendor 32 ch. head coil and a 2D GRE pulse sequence. Data were transferred offline and reconstructed in MATLAB. There are two parameters: 1) an averaging convolution kernel B (a box), and 2) the number of iterations. First, ρ is initialized to 1. Then at very iteration k: (a) the coil sensitivity for coil q is estimated as $C_q^k =$ (conj(ρ^{k-1}• x D_q) * B, (b) $\mathbf{C}^k$ is normalized, (c) ρ^k is re-estimated ρ^k = sum(conj(C_q^k) x D_q), and finally (d) any additional phase in the phased sum of C across channels is put into ρ, i.e. Ω = sum(C_q^k exp(-iϕ)) where ϕ is the angle of the average of $C_q^k\rho^k$ is put into **ρ**. This iterative scheme can be shown to be equivalent to using a power method for finding the first singular vector in each image patch of the size of B. The last phasing step insures that at every step as much of the phase as possible is in ρ, without introducing point discontinuities or branch cuts.

Results: Magnitude, phase, real, and imaginary for **D** (1a) and ρ (1b) and **C** (1c) are shown below for a box size of 7x7 pixels and 10 iterations. (For display, only 16 of the 32 channels are shown). Note that there are no phase singularities in the estimated coil sensitivities (as seen in the real and imaginary components).



Conclusion: In this work we presented a computationally efficient algorithm for estimating optimal coil sensitivities in a way that preserves the phase of the object in the combined image. This approach may be used in parallel imaging for auto-calibration and for the creation of a single virtual coil.

References: [1] Walsh et al. (2000) 43(5):682. [2] Inati et al. (2013) Proc. ISMRM 21:2672.