A Solution to the Phase Problem in Adaptive Coil Combination

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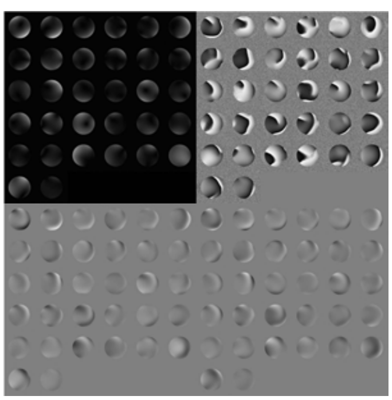
Target audience: Clinicians/researchers using coil arrays for phase sensitive imaging

Purpose: Optimal coil combination was shown by Roemer (1) to be a weighted sum of the complex individual coil images, with weights given by the relative coil sensitivities (B1), which in practice are unknown. An adaptive version was proposed by Walsh et al. (2) using a statistical description of the expected signal and noise covariances to derive an estimate of the optimal coil combination weights directly from the data. By solving for the relative coil sensitivities using covariances, only the relative phases between the coils are estimated. It is therefore necessary to reference the phases, and typically, one of the coils is chosen arbitrarily as the reference. In regions where the reference coil has low signal to noise ratio, the reference phase can be noisy and the phase of the estimated relative coil sensitivities is no longer smooth. This may result in problems when the application requires complex images. In this work we take a slightly different perspective and arrive at a solution that estimates the complex-valued relative coil sensitivity profiles in a way that enforces the smoothness of the phase. This approach mitigates the problems with phase and may be used in applications like susceptibility weighted imaging (3), complex interpolation, complex motion correction, referenceless thermometry, etc.

Methods: Data were acquired from a water phantom on a Siemens 3T Skyra scanner using the vendor 32 ch. head coil and a short TE GRE sequence. Data were transferred offline and reconstructed in Matlab. Coil combination weights were estimated by forming the (49x32) array **D** consisting of the data in a 7x7 region around each pixel and computing its first singular vector ($\mathbf{D} = \mathbf{v}\,\mathbf{c}^T$) and putting the average phase of **v** into **c** (normalized coil sensitivities). This is the least-squares fit to the data assuming smooth coil sensitivities over the ROI. From the adaptively combined images, the first step of SWI preprocessing was performed and homodyne filtered phase images were computed to demonstrate the sensitivity of the phase to errors (singularities) in coil-sensitivities.

Results:

Fig. 1: Original Data



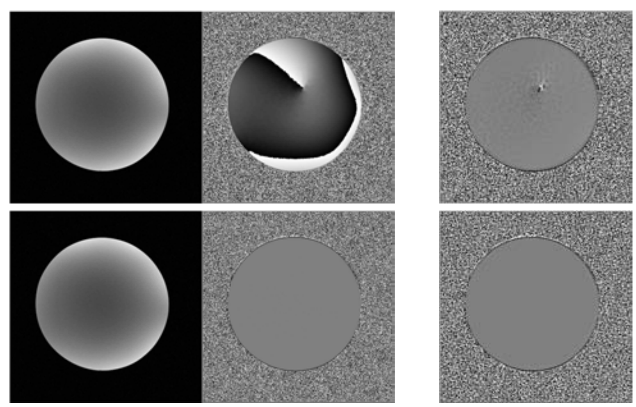
Mag, Ph, Re, Im. Note no phase singularities

Fig. 2

Adaptively combined images | Filtered Phase

Walsh method Coil 1 as ref.

Proposed method



Discussion: With surface coil arrays and parallel image reconstruction, coil sensitivity estimation and adaptive coil combination have become a fundamental step in image reconstruction. As part of the coil sensitivity estimation procedure, it is necessary to choose a reference for the phases, and typically, one of the coils is chosen arbitrarily as a reference. Wherever the reference coil SNR is low, the phase of the reference coil is noisy, leading to estimated sensitivities with non-smooth phase. This may result in problems when the application requires complex images. In this work we presented a simple algorithm for estimating the complex-valued coil sensitivity profiles in a way that enforces the smoothness of the phase. We demonstrated how this approach can mitigate the problems with phase and how it may be used in applications like susceptibility weighted imaging.

Conclusion: For many applications requiring the phase of the combined image, the proposed method solves a practical problem by ensuring smooth phase in the coil sensitivity estimates. The proposed algorithm has a fast implementation and can be easily incorporated into a reconstruction pipeline.

References: [1] Roemer et al. (1990) MRM 16(2):192. [2] Walsh et al. (2000) 43(5):682. [3] Haacke et al. (2004) MRM 52(3):612. [4] Kellman et al. (2005) MRM 54(6):1439–1447.