Automated Coil Subset Selection for Improved GRAPPA Reconstruction

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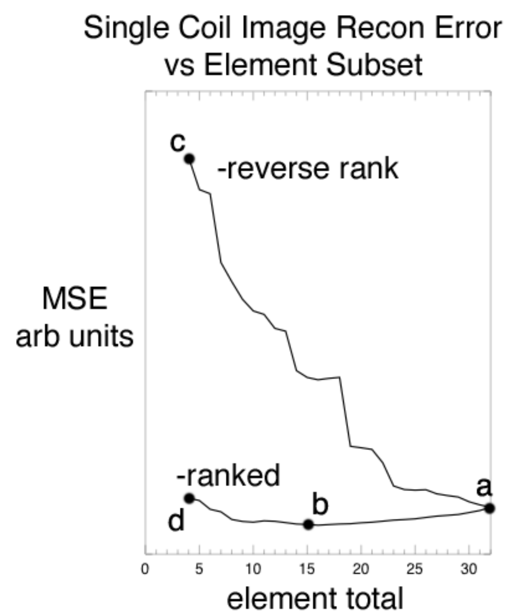
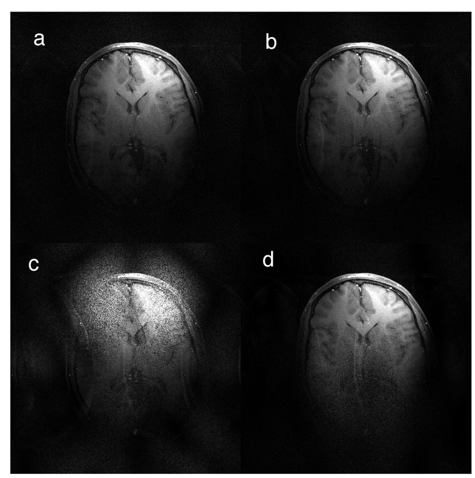
Overview. Parallel imaging with multiple receivers is a ubiquitous method in MRI, used both clinically and in basic science research. GRAPPA [1] based reconstructions aim to fill missing k-space data using a local weighted average of neighboring k-space signals acquired by multiple receiver elements. Given a limited set of auto-calibration data, the number of parameters to fit can rapidly approach the same order as the number of equations determined by the number of calibration data points. Over-fitting the calibration data makes the result to be sensitive to noise and unstable. At the opposite extreme under-fitting the data also results in poor reconstruction and residual aliasing artifacts. Both issues become more sensitive with high reduction factors, limited calibration data or high-channel coil arrays. A parsimonious choice of reconstruction kernel would minimize the residual fitting error of the model while simultaneously penalizing over-complex models. [2] So far, a neglected topic concerns whether or not to extend the kernel support to all available coils. Counter-intuitive to the idea that more channels results in improved image quality, the hypothesis of this paper proposes the following. For a given single-coil image reconstruction there exists a subset of coil elements which contribute more to reconstruction and another subset that overcomplicates the estimation model resulting in noise enhancement. In this "synthetic" coil direction of the kernel support there exists no metric to decide on what the neighborhood should be. Given a large array, an exhaustive search of all coil combinations is impractical. The second aim of this work demonstrates a coil ranking method based on the proximity of the coils in the array. Furthermore the metric is data driven a does not rely on prior knowledge of the coil geometry. Instead the coils are ranked by their cross-covariance with the assumption that coil elements that overlap similar regions of the object are more important.

Methods. GRAPPA data for R4 acceleration were generated by sub-sampling high-resolution T1-weighted k-space data (FOV 256 mm, matrix 512, NEX1) acquired on a 3 Telsa Siemens Verio (Siemens AG, Erlangen, Germany) using a product 32 channel head coil and assuming a calibration pre-scan of 16 auto-calibration lines. Respective to each coil element the other coils were ranked according to their maximum cross-covariance. The coil cross-covariance was computed by image domain multiplication by complex conjugates and inverse Fourier transform. [3] Using the coil ranking provided by the covariances, the kernel support in the "coil" direction was varied from 4 to 32 elements. In addition, the alternate situation of a reversed coil ranking was investigated to test the validity of the coil ranking method. The k-space extent of the kernel was determined as in Ref [2]. The fully sampled image was used as the gold standard for measuring the average mean-squared-error between different reconstructions strategies.





Results. A single element coil reconstruction is presented with both ranking schemes. The plots of MSE versus coil neighborhood size reflect the differences between the two subset selections. Of note is that as the number of coils included in the ranked kernel support the MSE reduces to a minimum near 15 elements then begins to rise again. The results show that the reconstruction given by 32 elements (a) for this particular single-coil image is not optimal, as the 15 element reconstruction (b) shows subtle improvement. The differences between the best 4 and worst 4 element choices (c,d) are significant.

Discussion. Conventional wisdom in parallel MR holds that increasing the number of coil elements always improves the image reconstruction. While that likely still holds when looking at the coil array as a whole after parallel reconstruction, the results presented here show that GRAPPA is improved when optimizing the reconstruction parameters on a coil by coil basis. Previous GRAPPA optimization methods have looked predominantly at determining the kernel support in k-space dimensions. The new findings presented here suggest the same procedure can be extended to a synthetic coil direction. The covariance ranking system is valid and leads to an optimal subset of coils half that of the total available, thus simultaneously reducing reconstruction times and improving image quality.

References. 1. Mark A. Griswold et al., MRM 2002; 47:1202-1210. **2.** K. Heberlein et al, ISMRM 2008. **3.** K. Heberlein et al, ISMRM 2006