Comparison of an Iterative GRAPPA Method to Compressed Sensing

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Introduction

GRAPPA can be difficult to implement when used with non-Cartesian trajectories due to the changing relationship between samples throughout K-space. We have developed an iterative GRAPPA method that simply uses repeated application of Cartesian GRAPPA interpolation following gridding. This approach expands on previous iterative methods [1,2] that have shown good results on non-Cartesian acquisitions. To evaluate the performance, we compare this method to a compressed sensing (CS) approach, which has been shown to perform well with highly undersampled radial acquisitions [3].

Methods

Images of a resolution phantom were acquired using a 3.0T Trio scanner (Siemens Medical Solutions) using a radial scheme with projections advanced by the Golden angle. Scan parameters were: of 180 cm FOV; 5mm thick; 128 samples; flip angle = 10°; TE/TR 2.1/6.7 ms; and sampling bandwidth 490 Hz/pixel. Sixteen spokes were acquired using a 4-element head coil. The projection data were gridded using a 3x3 Kaiser-Bessel convolution kernel and GRAPPA weights were calculated from the center 32 lines of those gridded samples. Alternate odd/even lines of K-space were interpolated using conventional Cartesian GRAPPA in an iterative manner. Since this step overwrites true measured data., these data were restored before the next iteration for all but the last two iterations. One and two stage GRAPPA post-processing routines were compared. Single stage GRAPPA used 3x4 or 4 x5 kernels with 4, 8, and 12 iterations. The two-stage GRAPPA applied an initial 8x9 kernel for 1 to 2 iterations followed by a 3x4 or 4x5 kernel for the remainder. The processing code was written in C++ and run on an Alienware PC with an Intel i7-930HT quad-core processor running at 2.80 GHz. Cross-correlation with a fully sampled image was performed to evaluate the effects of kernel size and number of iterations on image quality.

We compared GRAPPA with CS that used nonlinear inversion reconstruction performed with an iteratively regularized Gauss-Newton nonlinear inversion with total generalized variation (IRGN-TGV). The code (Knoll, et al (3)) was implemented in MATLAB (R2009b, The MathWorks, Natick, MA) on a PC with 8-cores (Intel Xeon at 1.6 GHz). We solve for the spin density u and unknown coil sensitivities $c = (c_1,\ldots,c_N)$ minimizing $\min_{dx} \frac{1}{2}\|F'(x^k)dx + F(x^k) - g\|^2 + W + TGV$, where F is the composite sampling operator, W a term to enforce smoothly varying coil sensitivity profiles, and TGV the generalized total variation. The resulting images were compared qualitatively and quantitatively.

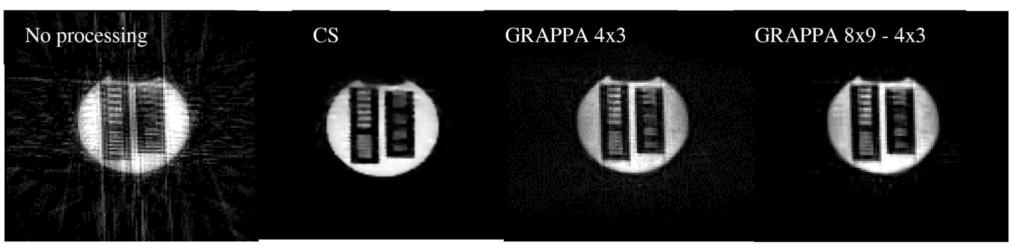

Figure 1. a) No processing; b) CS; c) GRAPPA single stage 4x3 using 12 iterations; d) GRAPPA two-stage 8x9 and 4x3 using 5 iterations.

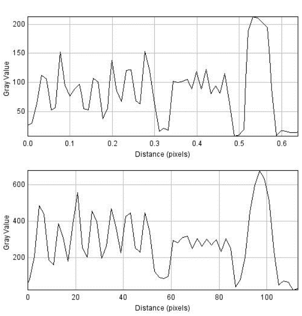

Figure 2. **top**) profile plot of left resolution targets for CS image. **bottom**) profile plot for two-stage GRAPPA

Results: Images from each reconstruction are shown in Figure 1. A profile plot across the left resolution targets is show in Figure 2. From cross-correlations with a fully sampled image, there was little difference between the images reconstructed with the different GRAPPA kernels; however, the two-stage reconstruction reached convergence with fewer iterations. The iterative GRAPPA scheme compares favorably with the CS reconstruction. The GRAPPA images have less streaking and better resolution whereas the CS image shows less shading. Processing time for the two-stage GRAPPA (using a total of 5 iterations) was 0.2 seconds. CS processing time in MATLAB was 2 minutes.

Conclusion: An iterative auto-calibrating GRAPPA method was developed and compared to a compressed sensing method. Images compared favorably. This method is simple to implement and executes rapidly in that is based on a simple Cartesian GRAPPA core. GRAPPA routines that have been developed for Cartesian sequences can be adapted for more general use.

References: 1)Lustig M, Pauly JM. Proc ISMRM 2007 (Berlin). **2**) Blaimer, et al. Proc ISMRM 2009 (Honolulu). **3**) Knoll F, et al. Magn Reson Med. 67, 2012.
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