Phase-Constrained Reconstruction of GRAPPA for Accelerated MR Acquisitions

M. Sabati[1,2], H. Peng[1,2], and R. Frayne[1,2]

[1]Radiology, University of Calgary, Calgary, AB, Canada, [2]Seaman MR Research Centre, Foothills Medical Centre, Calgary Health Region, Calgary, AB, Canada

Introduction

Scan time reduction is important in clinical MR imaging. Partial Fourier acquisitions rely on the conjugate symmetry of Hermitian data, allowing for shorter scan times due to fewer phase-encoding steps. Calculation of the full **k**-space data is usually accomplished by *direct* conjugate synthesis (*e.g.*, homodyne reconstruction [1]) or by *iterative* constraint-based algorithms (*e.g.*, projection-onto-convex sets, POCS, [2]). Even faster image acquisition has been achieved by combining partial Fourier acquisitions with parallel imaging.[3,4] For example, the POCS formalism has been used to reconstruct sensitivity-encoded MR data in an iterative POCSENSE procedure.[3] Intuitively however, the **k**-space-based parallel imaging formalisms (such as GRAPPA [5]) are, more compatible with partial Fourier methods because the synthesis of the final image can be done in **k**-space *prior* to partial Fourier reconstruction.

Here, we propose a combined GRAPPA+POCS (GRAPOCS) technique that allows simple and efficient inclusion of phase- and data-consistency constraints in image reconstruction in order to improve image quality at higher acceleration rates. Initial results from phantom and healthy volunteers data show good-quality images with acceleration rates greater than number of the coil elements.

Materials and Methods

Fully sampled **k**-space data sets were collected on a 3.0 T clinical MR scanner (Signa; GE Healthcare, Waukesha, WI) using a vendor-supplied quality assurance phantom and volunteers. Images were acquired using a 4-element torso array coil. A 2D fast gradient-recalled echo sequence (TR/TE/flip = 8.1ms /3.2ms /60°; 22-cm FOV; 256 × 256 acquisition) was used to image the phantom. A 2D fast spin echo sequence (TR/TE/flip = 217ms /20ms /45°; 32-cm × 16-cm FOV; 256 × 256 acquisition) was used to image the legs. Partial **k**-space parallel acquisitions with accelerations rates of R = 2, 3, 4, and 5 were emulated by acquiring only every second or third phase-encoding line of one side of **k**-space (*i.e.*, positive k_y) and removing all but the central 32, 16, or 8 phase-encoding lines of the **k**-space. These central lines were used as auto-calibration signals (ACS) for GRAPPA and for estimating the low-resolution phase map in POCS reconstruction. Three methods of image reconstruction on the partially sampled **k**-space data were investigated: (i) conventional GRAPPA reconstruction, [5] (ii) POCS+GRAPPA: POCS **k**-space reconstruction was first performed followed by GRAPPA, and (iii) GRAPOCS: GRAPPA **k**-space reconstruction followed by POCS. A conventional sum-of-squares (SOS) reconstruction method was also performed on fully sampled data from all coil elements and used as reference.

Results

Figures 1 and 2 show the phantom and axial images in the legs using the four reconstruction methods described above. In each case, the SOS images had the best quality and highest signal-to-noise ratios, as expected, but had no scan time reduction effect (R = 1). For the same scan time reduction factor, R, the GRAPPA images appeared blurred compared to other methods. The POCS-based reconstructed images had higher resolution and low residual aliasing, particularly the preferable GRAPOCS implementation order (compare Figure 1c and 1d). For higher acceleration factors, the improvement in image quality was even greater for GRAPOCS, particularly when R > number of coil elements (Figure 2, last row).

Discussion and Conclusions

To accelerate MR scans, it is often desirable to use partial Fourier acquisition in conjunction with parallel imaging. Because POCS reconstructs complex data and includes phase information, it is beneficial to use this method in conjunction with auto-calibrated parallel imaging methods. Here, we demonstrated the use of POCS with GRAPPA. As with GRAPPA, the proposed GRAPOCS method provides un-aliased images from each component coil *prior* to image combination but results in better image quality for greater accelerations rates.

We have combined two reconstruction methods each of which is known to be effective for scan time reduction. The inherent ACS lines acquired in GRAPPA are synergistic with the need for estimation of a low-resolution phase map in POCS.

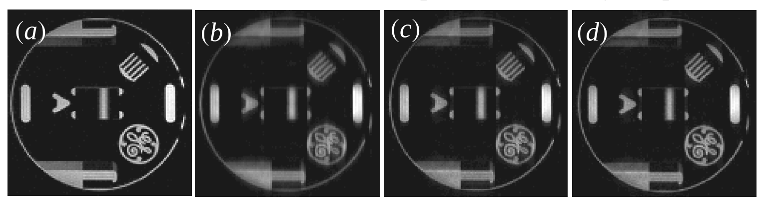
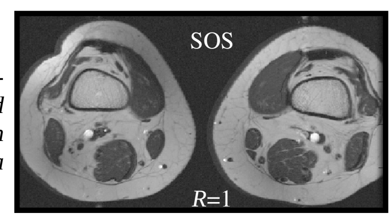


*Figure 1: Phantom results using (a) SOS (R=1), and (b) GRAPPA, (c) POCS+GRAPPA, (d) GRAPOCS reconstructions with accelerated **k**-space acquisition rate of R=3.*



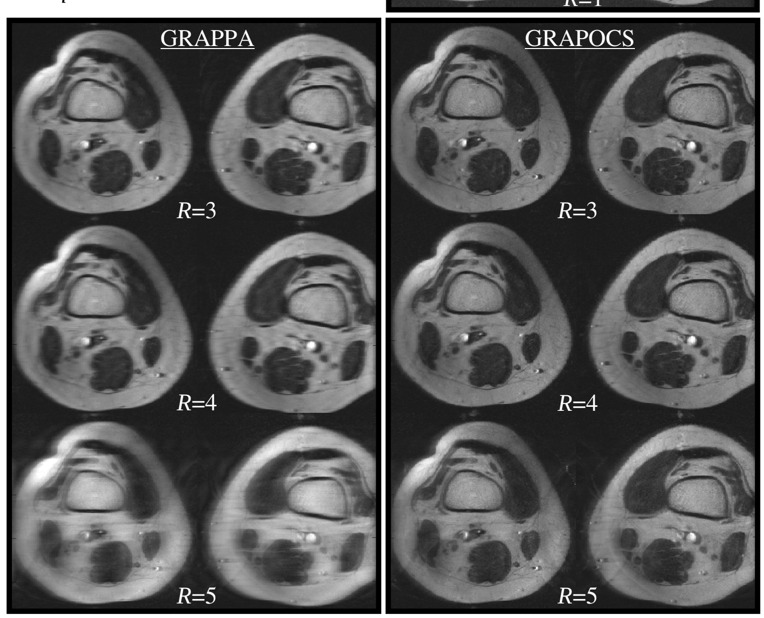


Figure 2: Axial images from volunteer legs using SOS, GRAPPA, and GRAPOCS reconstructions with simulated R = 3, 4, and 5. Data acquisition used a 4-element coil.

References

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