Reconstruction of Arbitrary Non-Cartesian Trajectories using Pseudo-Cartesian GRAPPA in Conjunction with GRAPPA Operator Gridding (GROG)

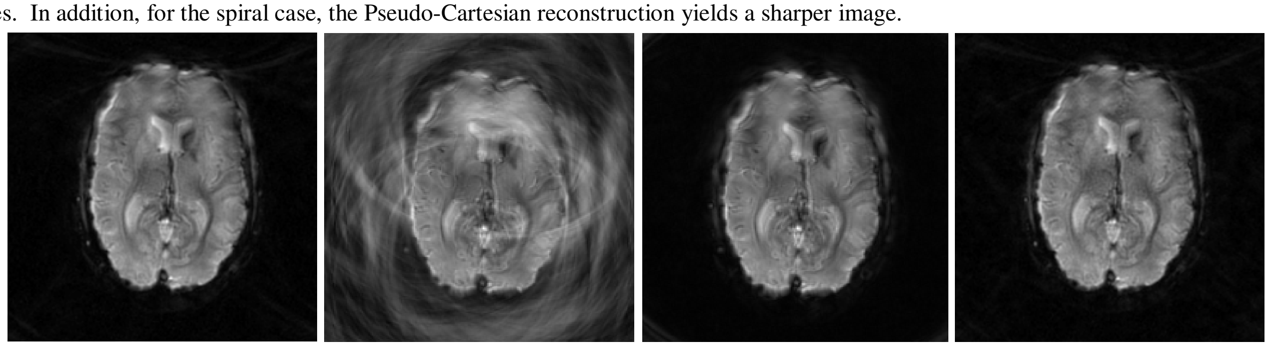
N. Seiberlich[1], F. A. Breuer[2], R. M. Heidemann[3], M. Blaimer[4], M. A. Griswold[4], and P. M. Jakob[1,2]

[1]Department of Experimental Physics 5, University of Wuerzburg, Wuerzburg, Germany, [2]Research Center Magnetic Resonance Bavaria (MRB), Wuerzburg, Germany, [3]Siemens Medical Solutions, Erlangen, Germany, [4]Department of Radiology, University Hospitals of Cleveland, Cleveland, OH, United States

Introduction: The recently introduced GRAPPA Operator Gridder (GROG) [1] has been shown to be useful for the regridding of fully-sampled non-Cartesian data. However, GROG can also be used to properly regrid undersampled non-Cartesian data, which cannot be performed with other common regridding schemes, such as the gold-standard convolution-based gridding [2]. GROG has the advantage that single non-Cartesian points are shifted to the nearest Cartesian point using the GRAPPA Operator, leaving empty spaces in k-space where data must be reconstructed; convolution gridders assume that the Nyquist criterion is fulfilled, and any "holes" in k-space lead to gridding errors, but not missing k-space points. After regridding the undersampled non-Cartesian data with GROG, Pseudo-Cartesian GRAPPA [3] can be performed, thereby reconstructing the missing points in k-space. This method eliminates the need for specialized non-Cartesian reconstruction algorithms, as the data can first be regridded and then reconstructed using a small number of simple Cartesian GRAPPA patterns. In addition, trajectories for which no non-Cartesian GRAPPA reconstruction currently exists, such as the rosette [4] trajectory, can be accelerated and reconstructed using Pseudo-Cartesian GRAPPA.

Methods: In vivo spiral data were acquired using a 3T MR scanner (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany) equipped with an eight channel head array coil (MRI Devices Corporation, Waukesha, WI), and rosette data were simulated using a brain phantom and an eight-element head array coil. The data were first appropriately undersampled (i.e. phase encoding steps were removed), resulting in R=2 (2 arms, 7289 read points, base matrix 192x192) for the spiral data and R=3 (21 phase encoding steps, 512 read points, base matrix 128x128) for the rosette data, and the resulting undersampled data were regridded using GROG. After examining the regridded, undersampled data, several Cartesian GRAPPA patterns were selected, and the missing k-space points reconstructed using these patterns and Pseudo-Cartesian GRAPPA. Calibration data were taken from separately acquired low-resolution Cartesian datasets. For the spiral data, the standard spiral GRAPPA reconstruction [5] was performed to compare the performance of Pseudo-Cartesian GRAPPA to the gold-standard. For the rosette data, there is currently no GRAPPA technique which can reconstruct the undersampled trajectory; thus, the Pseudo-Cartesian reconstruction was compared only to the reference image.

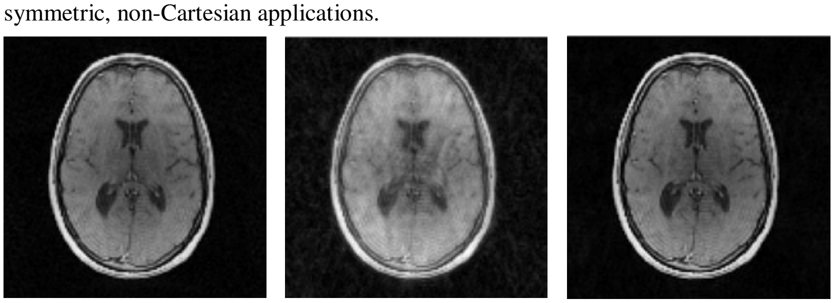
Results: Figure 1 shows the reference, undersampled, gold-standard GRAPPA reconstruction, and GROG Pseudo-Cartesian reconstruction images for the R=2 spiral trajectory. Figure 2 shows the reference, undersampled, and Pseudo-Cartesian reconstruction of the R=3 rosette data. The GROG Pseudo-Cartesian reconstructions for both the spiral and rosette trajectory clearly remove the aliasing artifacts seen in the undersampled images. In addition, for the spiral case, the Pseudo-Cartesian reconstruction yields a sharper image.



Reference R=2 Undersampled Spiral GRAPPA Pseudo-Cartesian GRAPPA

Figure 1: The reference, undersampled, reconstructed spiral GRAPPA, and reconstructed GROG Pseudo-Cartesian images for a R=2 in vivo spiral dataset.

Discussion: By first applying GROG to undersampled non-Cartesian data, they can be regridded while retaining the "holes" in k-space that must be filled using a reconstruction algorithm. The subsequent application of Pseudo-Cartesian GRAPPA allows the reconstruction of any non-Cartesian trajectory, including trajectories which do not have a high degree of symmetry, which is usually required for a GRAPPA reconstruction. Thus, the algorithm proposed here is far more general than other non-Cartesian GRAPPA reconstructions and can be used in a variety of non-symmetric, non-Cartesian applications.



Reference R=3 Undersampled Pseudo-Cartesian GRAPPA

Figure 2: The reference, undersampled, and reconstructed GROG Pseudo-Cartesian images for a R=3 simulated rosette dataset.

References

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