Iterative and joint reconstruction from calibration and image data for parallel imaging

Y. Li[1], and C. L. Dumoulin[1]
[1]Radiology, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, United States

Introduction: The work presented here introduces a new approach to reconstructing images iteratively and jointly from calibration and acquired image data in parallel imaging for accelerating data acquisition in MRI. Unlike a conventional parallel imaging technique that seeks a reconstruction solution "unidirectionally" from calibration to image data [1, 2], the new technique optimizes the reconstruction "bidirectionally" between low resolution/fully sampled calibration data and high resolution/undersampled image data. This bidirectional optimization offers high image quality when either, or both, of the calibration and image data are not sufficient for a conventional reconstruction technique, thereby improving parallel imaging performance. In a high resolution brain imaging experiment, we investigated the ability of the iterative and joint reconstruction to accelerate imaging by increasing the undersampling factor and reducing the calibration data. It was demonstrated that the new technique allows for the use of a higher undersampling factor and/or less calibration data than a conventional technique.

Methods and Materials: In parallel imaging, calibration data are fully sampled and have low resolution, while the acquired image data are undersampled and have high resolution. A conventional parallel imaging technique seeks a reconstruction solution using the calibration data to estimate the mathematical relationship from undersampled (reduced field of view) to fully sampled (full field of view) data. It should be known that the undersampled image data contain information about the mathematical relationship from low (center k-space) to high (outer k-space) resolution data, and this information can be used to improve the resolution of calibration data and in turn the reconstruction of the image. In the presented work, we developed a technique that takes advantage of this additional information for improved parallel imaging. Fig. 1 shows the flow chart of this new technique. In the first iteration, this iterative and joint reconstruction uses calibration data to generate a reconstruction solution in the same way as a conventional reconstruction technique. Then the reconstructed data are used to calibrate the mathematical relationship from low to high resolution data. This relationship is then used to create new high-resolution calibration data that will be used in the following iterations to improve the image reconstruction.

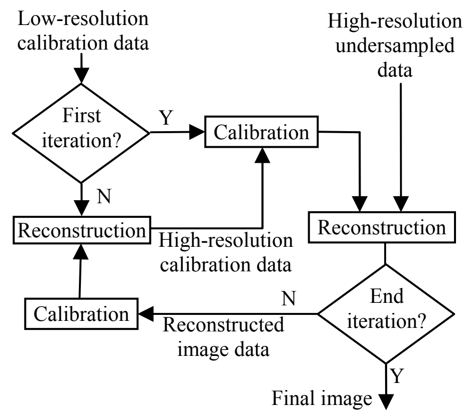

Fig. 1 *Flow chart of iterative and joint reconstruction for parallel imaging.*

In this work, the iterative and joint reconstruction was investigated in brain imaging using an 8-channel coil array (Invivo, Gainesville, FL) on a 3T MRI scanner. A set of axial images was acquired with full Fourier encoding using a T_1 FLAIR sequence (FOV 220×220 mm, matrix size 512×512, TR 3060 ms, TE 126 ms, flip angle 90°, slice thickness 5 mm, number of averages 1). The phase encoding direction was left-right. In parallel imaging reconstruction, Auto-Calibration Signals (ACS) were used. Both ACS and undersampled image data were generated manually from the fully sampled data in post-processing. A standard GRAPPA technique [2] was used as a reference. The iterative and joint reconstruction was compared with GRAPPA using the same data for reconstruction. To reconstruct calibration data with higher resolution in each iteration, the relationship from low and high resolution data was represented by a convolution kernel (size 17×5) in k-space and the convolution was applied to the low-resolution ACS data.

Results and Discussion: As an example, Fig. 2 shows the iterative and joint reconstruction from 12 ACS lines and data undersampled by a factor 4. From the results of three iterations, it can be seen that every iteration shows "joint" improvement in the reconstruction of the calibration image and the acquired image: The resolution of calibration image is increased and the aliasing in the acquired image is reduced. There is no considerable difference in image reconstruction between 2nd and 3rd iterations implying the convergence is fast. Fig. 3 shows the comparison of GRAPPA and joint and iterative reconstruction with 2 iterations using several data sets. It can be seen that the level of residue aliasing artifacts in GRAPPA increases dramatically if the number of ACS lines <24 or the undersampling factor R >4, while the iterative and joint reconstruction performs very well. Even when only 8 ACS lines and an undersampling factor R=5 are used, the new technique still provides good image quality. This demonstrates that the iterative and joint reconstruction needs less data than a conventional technique and has the potential to increase the acceleration capability of parallel imaging. This gain should be attributed to the use of more information in parallel imaging than a conventional technique.

Reference: [1]. Prussmann, K.P. et. al., MRM 1999, 42: 952-962. [2]. Griswold, M. A. et. al., MRM 2002, 47:1202-1210.

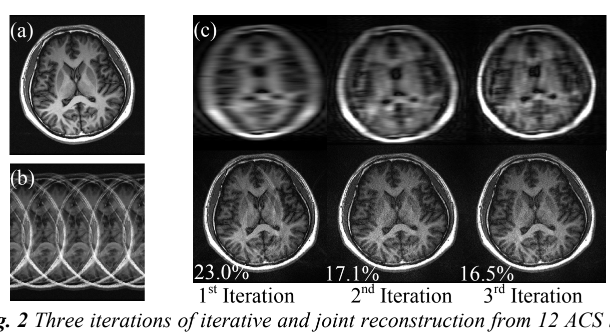

Fig. 2 *Three iterations of iterative and joint reconstruction from 12 ACS lines and data undersampled by a factor 4. (a) Reference image from fully sampled data in high resolution brain imaging. (b) Initial image from undersampled data. (c) Reconstructed images from 3 iterations. Top row shows the reconstructed images from calibration data: Resolution is iteratively improved. Bottom row shows the reconstruction of acquired image: Aliasing is iteratively reduced. The percentage numbers are the calculated root-mean-squared errors with respect to the reference image.*

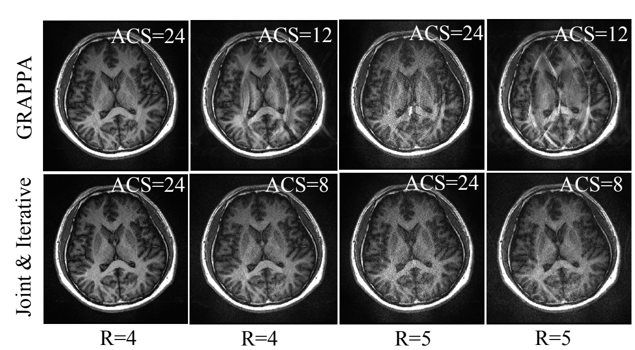

Fig. 3 *Comparison of GRAPPA and iterative and joint reconstruction. Top row shows GRAPPA reconstruction. Bottom row shows the iterative and joint reconstruction. GRAPPA performs well when R=4 and ACS=24. When R>4 or ACS<24, GRAPPA gives strong aliasing artifacts. Iterative and joint reconstruction provides good image quality even when ACS=8 and R=5, indicating this parallel imaging technique has higher acceleration capability.*