A Self-Calibrated Parallel Imaging Method for Radial Trajectories

A. Arunachalam[1], A. A. Samsonov[2], W. F. Block[2]
[1]Electrical Engineering, UW-Madison, Madison, Wisconsin, United States, [2]Medical Physics, UW-Madison, Madison, WI, United States

INTRODUCTION

A self-calibrated Parallel Imaging method with low reconstruction times is presented for two and three dimensional radial trajectories. A limitation of the radial GRAPPA [1] method is the need for acquiring training data prior to the accelerated scan. This has been eliminated with the introduction of self-calibration into the reconstruction process. The radially over sampled center of *k*-space is used to estimate individual receiver sensitivity profiles. Receiver sensitivities are then reintroduced in the image domain and the prohibitively large matrix inversion procedure is completed entirely in *k*-space by performing a small number of fast matrix inversions. The in-vivo applicability of the method for 2D radial applications is demonstrated with an example of abdominal imaging for acceleration factors of 2 and 4. The proposed method was used in combination with a pure 3D radial trajectory [2] to reduce the trade-off between spatial and temporal resolution in 3D CE-MRA. In CE-MRA, radial datasets from accelerated 3D scans were processed by the technique to improve signal content in vessels, reduce undersampling and provide 3D isotropic resolution to achieve full coverage of the torso in 14 seconds.

MATERIALS AND METHODS

The aim of this technique is to synthesize the unacquired projections in an accelerated scan using only an approximation of the training data set used in radial GRAPPA. The fully sampled region in the oversampled center of radial *k*-space is identified and low resolution artifact free images are generated for individual receivers. A low resolution sum-of-squares image is obtained and individual low resolution receiver images are divided by this composite image to obtain estimates of the receiver spatial sensitivity profiles. As shown at the top of Figure 1, a composite image is formed using a conventional regridding reconstruction. The N_{Proj} projections acquired during the accelerated scan are processed separately for each receiver before combining them to produce a composite image in which aliased energy is present. This image is equivalent to the first approximation of the true solution obtained using the Jacobi iterative method. Progressing down Figure 1, the composite image is multiplied with individual coil sensitivity profiles, forward *FFTed* to obtain Cartesian *k*-space data, and is inverse gridded (IG) onto 2 or 3-dimensional radial grid consisting of the desired number of projections in the unaccelerated scan. In the example of a 2D case where a 256 projection scan is to be accelerated by only acquiring 64 projections (N_{Proj}= 64), Cartesian *k*-space data would be resampled onto a radial grid with 256 projections during this step. This data, instead of the training data in radial GRAPPA, is used to compute the reconstruction weights in the process labeled KW. The missing projections are synthesized in the step labeled KR as a linear combination of the initially acquired projections, in proportion according to the reconstruction weights. Since the composite image used in Fig.1 is an approximation of the true solution, this approximation can be further refined by first running several iterations of the method proposed in [3] prior to processing by the algorithm.

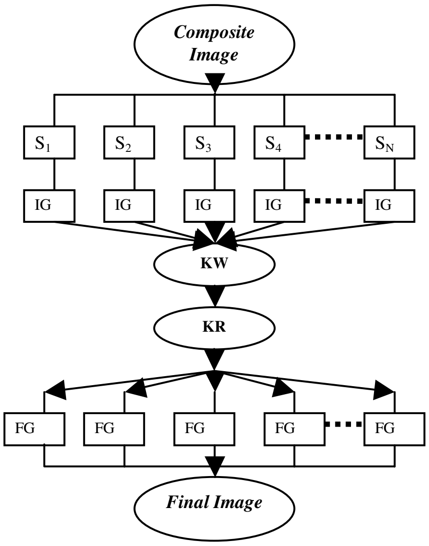

Figure 1. S_n- Sensitivity map of coil where n denotes the appropriate coil number are multiplied by composite image. **IG**- Inverse gridding block that using forward FFT to obtain 2D/3D Cartesian *k*-space which is inverse gridded onto a radial trajectory with the desired number of *k*-space projections. **KW**- Radial data used to compute reconstruction weights. **KR**- Synthesize unacquired radial lines. **FG**- Forward gridding block grids synthesized radial data onto a 2D/ 3D Cartesian grid. The gridded data is FFTed onto the image domain.

RESULTS AND DISCUSSION

2D data processing was implemented in MATLAB 6(Natick, USA) and all 3D data processing was implemented in the C language on a 1 GHz Athlon PC processor. 2D data was acquired using a four-channel phase array coil and 3D data was acquired using an eight channel array. All data was collected on a GE Signa twin-speed 1.5T system. The algorithm's performance is illustrated in Figure 2. From an initial projection number N_{proj} equal to 64, the reconstruction time for computing the weights and synthesizing the desired projections of 128 and 256 was 1.2 and 2.4 seconds respectively. The unoptimized gridding and FFT routines took 1.2 seconds per coil. Figure 3 compares axial images of a pre and post processed CE-MRA image volume to demonstrate the improvement in CNR achieved. For a readout resolution of 256, N_{proj} equal to 16000 and acceleration factors of 2 and 3, the time taken to compute the weights, synthesize unacquired data, perform unoptimized 3D gridding and FFT operations were 4 and 6 minutes respectively. The time to compute just the weights and synthesize the data was 20 and 30 seconds respectively. Total reconstruction error was estimated using the method described in [4]. In 2D radial imaging, the error for acceleration factors of 2 and 4 was 0.0177 and 0.0201 respectively. For 3D reconstruction, the total error for acceleration factors of 2 and 3 was 0.0358 and 0.0392. The entire reconstruction process relies on an approximation of the training data and well as *k*-space locality to obtain the final output. The impact of both these approximations on the final image quality will be further investigated.

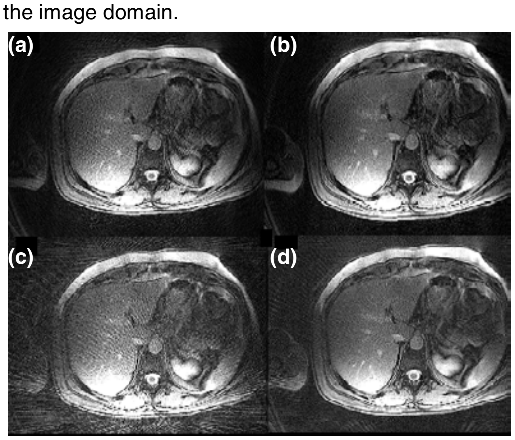

Figure 2. (a,b)Final images obtained after processing (a) 64 and (b) 128 projections in initial image. (c,d) Initial composite images using 64(c) and 128 (d) 2D radial lines respectively. The algorithm significantly reduces undersampling artifacts.

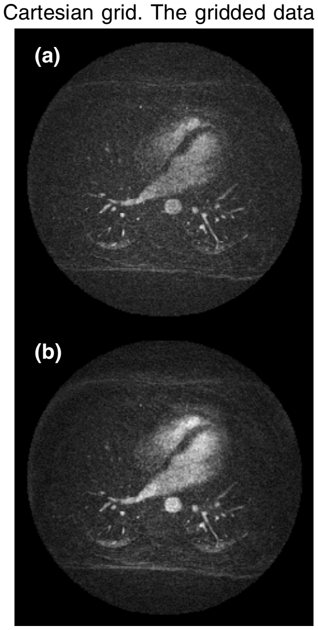

Figure 3: (a) Axial slice from an accelerated VIPR CE-MRA exam. (b) Same slice after processing with new algorithm shows improved signal in vessels and more homogenous background by effectively reducing undersampling.

CONCLUSIONS

The proposed method avoids the need for training data in radial GRAPPA while maintaining its reconstruction efficiency. It may be applied to several dynamic 2D radial imaging applications to limit streak artifacts and breathold durations or increase temporal resolution. Applying this method to 3D PR trajectories may permit greater acceleration factors in time-resolved 3D CE-MRA.

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