Modified PARS reconstruction for non-Cartesian parallel MRI

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Introduction

Parallel imaging with Augmented Radius in k-space (PARS) uses a k-space locality criterion to select a subset of acquired MR signal data to include in a generalized encoding matrix reconstruction [1]. It has proven effective for parallel MRI with spiral trajectories to improve image quality [2]. When PARS is applied for non-Cartesian trajectories, the primary difficulty is the extremely high computational intensity because invert of a restricted encoding matrix has to be performed for each target grid point. In this study a modified PARS is introduced to significantly reduce its computational complexity and consequently make it more feasible for non-Cartesian parallel MRI.

Method

Two modifications are made to non-Cartesian PARS to accelerate reconstructions. Firstly the harmonic fit, which is the key procedure of the encoding matrix invert, is performed in Fourier domain of coil sensitivities. Since coil profiles are usually slowly varying functions, they can be represented in Fourier domain by only a small number of data points. In this way the size of matrix to be inverted can be significantly reduced and hence the harmonic fit becomes much cheaper in computation. For example, normally a 64×64 sensitivity map can be well represented by less than *100* numbers in Fourier domain, thus the matrix in harmonic fit reduces from 64×64 rows to less than *100* rows. Secondly, the k-space trajectories are segmented according to their geometric characteristics, and reconstruction parameters are computed for each target trajectory segment instead of for each target grid point. In radial and spiral trajectories near points usually have similar relative shifts from their neighbor points, and reconstruction weights only depend on these relative shifts. As such, the target points in one small segment can share one set of reconstruction weights. As an example, Fig. 1 shows a segment in *2X* PARS for radial trajectory. The two target points are reconstructed using several neighbor points. The relative shifts of these two reconstructions are nearly identical and the same weights can be used for them. The validity of this simplification has been demonstrated in some previous works [3, 4]. By this two means, the computation time for non-Cartesian PARS can be dramatically reduced. One should note that the simplifications described above both introduce some approximations in reconstruction, and will inevitably cause degradation of accuracy in harmonic fit and reconstructions. Fortunately, in our experience, the degradation of image quality caused by these simplifications is not obvious and in most cases can be ignored.

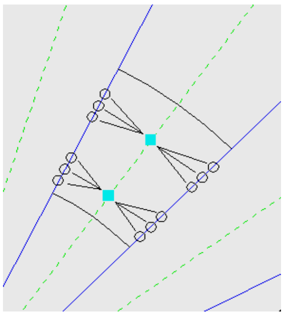


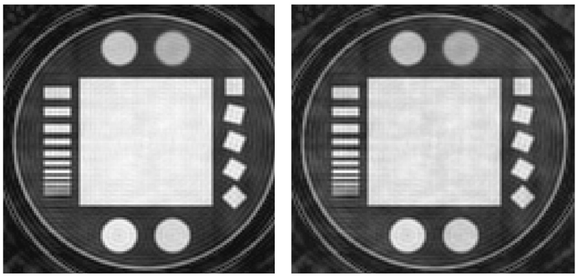
Fig. 1. A segment in modified *2X* PARS reconstruction for radial trajectory

This modified PARS reconstruction is implemented as the following procedures: (a). Sensitivity of each coil is calibrated and represented in Fourier domain, denoted as *Fourier_sen(ci)* with *ci* representing coil index; (b) The k-space is segmented along the sampling trajectories. Usually the size of these segments are not equal and depend on their local geometries; (c) For each segment, the relative shifts are identified and a harmonic fit is performed with each column of the matrix is a shifted version of *Fourier_sen (ci)*. (d) The missing trajectory segments are reconstructed using the parameters provided by procedure (c); (d) After the missing k-space points are reconstructed, convolution-based gridding and FFT are implemented to produce final images.

Results

64×64 sensitivity maps of a 4-element coil array were simulated using Biot-Savart equation. These sensitivities were then used with a phantom image to produce a set of 1536×3 spiral data. These data were reconstructed to 1536×6 samples using *2X* PARS. For comparison, the original PARS and the modified PARS we proposed were implemented respectively. In the modified PARS, the 64×64 coil sensitivity was represented by *100* Fourier coefficients. Each spiral segment was divided into *120* sub-segments with smaller size near central k-space and larger size in outer region.

The computation time required by each harmonic fit was *1.8s* in original PARS, and *0.17s* in the modified PARS. To finish the k-space reconstruction, original PARS required more than *3* hours on a P4 1.8G computer, while the modified PARS only required *105* seconds. After gridding (not required in original PARS) and FFT, the images produced from these two reconstructions are displayed in Fig. 2a and Fig. 2b, respectively. It is shown that the modified PARS does not cause obvious image quality degradation compared with original PARS.



(a) (b)

Fig. 2. Simulated reconstruction results of a phantom image by: (a) original PARS reconstruction (b) the modified PARS. In both implementations 1536×3 spiral samples are reconstructed to 1536×6 samples.

Conclusion

A modified PARS reconstruction method for non-Cartesian parallel MRI has been proposed. Harmonic fits are performed in the Fourier domain of coil sensitivities, and reconstructions are performed segment by segment instead of point by point. Preliminary results have shown that these two modifications can reduce the computation time by two orders compared with original PARS without obvious loss of SNR.

Acknowledgement

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References

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