Multi-Resolution Successive Iteration (MRSI) For Non-Cartesian SENSE Reconstruction

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Introduction

The iterative SENSE technique, which combines the conjugate gradient (CG) approach and the gridding principle [1], has greatly facilitated non-Cartesian SENSE reconstruction. However, usually the reconstruction time is still long because each iteration loop involves full k-space gridding procedures. In this work an improved reconstruction strategy — the multi-resolution successive iteration (MRSI) method is proposed for non-Cartesian SENSE. The basic idea is to divide the reconstruction into several successive phases with different level of resolution. At the first stage, only the central k-space is employed and a low-resolution image is generated with iteration. This low-resolution image is then used as the initial guess for the next iteration phase with higher resolution and using a larger portion of k-space. In such a fashion, the iteration approaches the desired image with increasing resolution. Early stages of reconstruction only cost a small amount of time since they involve gridding of a small portion of k-space. In vivo results show that the total reconstruction time can be significantly reduced with this novel method.

Method

Following the notations in Ref. [1], parallel imaging with arbitrary trajectories can be formulated by solving a large linear system: $(E^H DE)v = E^H Dm$, (1)
where E is the encoding matrix, D is the density correction matrix, m contains k-space samples, and v contains pixels of the reconstructed image.
For efficiency, Eq. (1) is solved iteratively using the CG method. The most time-demanding matrix-vector multiplication is performed using a gidding/FFT procedure. Conventionally a zero-image is employed as the initial guess, and each iteration loop involves a gridding and an inverse gridding of the full k-space.
As the early stages of iteration contribute little to the final accuracy of the reconstruction [2], we replace the early stages of full k-space iteration with a much cheaper low-resolution reconstruction. The MRSI algorithm is illustrated in Fig. 1. A 128*128 reconstruction is implemented in the following procedures:
(a).the 32*32 key hole of k-space is extracted and the CG iterative reconstruction is performed with this partial k-space. A zero-image is used as the initial guess. The iteration is stopped with the δ-criterion [1] and a 32*32 image is produced;
(b).the 64*64 central k-space is used for a 64*64 reconstruction. The former 32*32 image is enlarged to 64*64 by FFT/zero-padding/IFFT and serves as the initial guess of the 64*64 reconstruction. After CG iteration, a 64*64 approximate image is produced;
(c).the 64*64 image is enlarged and serve as the initial guess of the 128*128 reconstruction with full k-space to generate the final image.

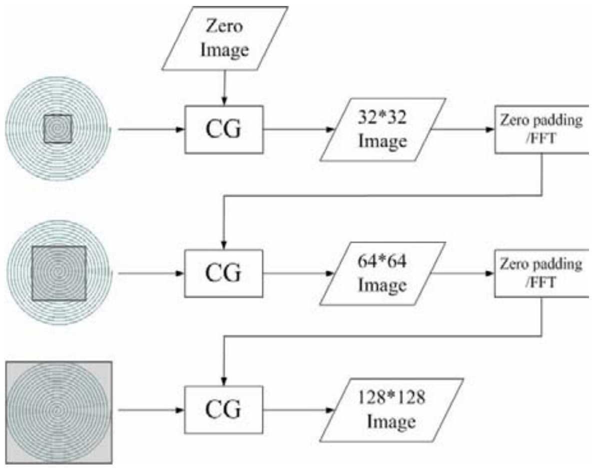

Fig. 1. Schematics of the MRSI algorithm

Results

Spiral MRI experiments of human brain were performed on a Siemens 3T system with an 8-element head coil. A full dataset of 4 interleaves were acquired and only one was extracted for reconstruction to simulate 4X acceleration. Iterative SENSE reconstructions using conventional CG iteration method and the MRSI method were performed respectively. The gridding procedures were implemented using the LS-nuFFT algorithm [3]. The progressions of the reconstructions are displayed in Fig. 2. To achieve good image quality, 40 iteration loops was required for conventional method. Fig. 2a shows the intermediate images after 1, 10 and 40 iteration loops. Using the MRSI method, to achieve comparable image quality, a combination of 8 iteration loops with 32*32 image, 10 loops with 64*64 image, and 24 loops with 128*128 image was required. The three images in Fig. 2b correspond to the results of the 32*32 iteration, the 64*64 iteration and the final 128*128 iteration, respectively.
The running time per iteration cycle with different image resolution is presented in Table 1. The total computation time of this reconstruction was 0.72*40=29s for conventional method, and 0.04*8+0.15*10+0.72*24=19s for the MRSI method. 34% time was saved with the MRSI method for this reconstruction.

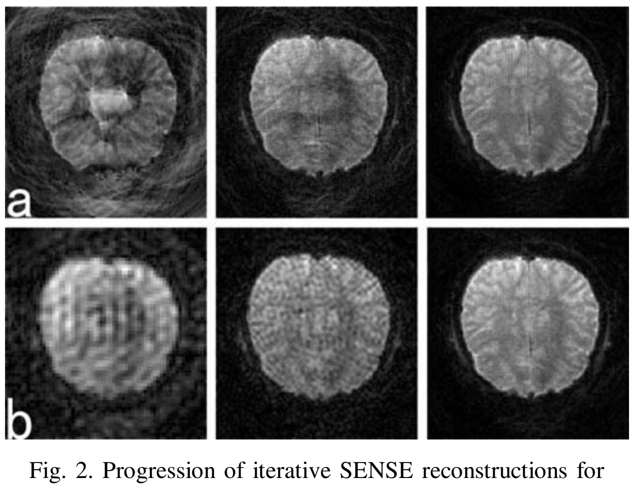

Fig. 2. Progression of iterative SENSE reconstructions for spiral brain imaging: (a). using the conventional CG method. (b). using the MRSI algorithm.

Table 1. Time cost per iteration loop vs. resolution

resolution	32*32	64*64	128*128
time cost per loop	0.04 s	0.15 s	0.72 s

Conclusion

A novel multi-resolution successive iteration (MRSI) algorithm for non-Cartesian SENSE reconstruction has been proposed. The CG iteration is performed in several phases with increasing resolution. Spiral results have shown that the total reconstruction time can be significantly reduced.

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References

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