An Experimental Comparison of Super-resolution Techniques in 2-D Multi-slice MRI

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Introduction

Most super-resolution reconstruction (SRR) techniques proposed for MRI to date have involved multiple multi-slice acquisitions with sub-pixel shifts in the slice-selection or phase-encoding direction [1-3]. In [4], we introduced a SRR technique called "Multi-stack" (MS), which instead of using sets of parallel shifted scans (PS), uses multiple multi-slice stacks of the same object, scanned at different orientations, rotated about the frequency-encoding axis. Combination of multiple multi-slice acquisitions are an alternative to 3-D Fourier imaging for obtaining isotropic 3-D resolution, attractive in long-TR imaging where 3-D Fourier imaging requires unrealistically long scan times. In this work we compare the MS and PS methods with a real scanning experiment using 2-D Inversion Recovery acquisition.

Materials and Methods

A static object (a grapefruit) was imaged to avoid possible motion during or between stacks. Two sets of six scans were acquired by the MS and the PS protocols on a 1.5T Philips Intera Scanner (R11), with otherwise identical parameters: TE=40ms, TR=3000ms, TI=190ms, flip angle=90°, 256x256 pixels on a 160mm in-plane square field of view, using partial-Fourier acquisition; contiguous slices of 3.6mm thickness with odd and even slices acquired in separate packages to avoid excitation crosstalk; in-plane resolution = 0.6mm; scan time 3 min per stack. The readout direction, common to all scans, was selected orthogonal to the transverse plane. The angle between consecutive scans for the MS method is 30°. The five sub-pixel shifts from the reference scan all shared 0.6 mm increments. The slice profile of the scans, used in calculating the contribution model for the iterative reconstruction procedures, was determined using a separate scan of a resolution phantom. The isotropic voxel size of the resultant reconstructions is $(0.6\ mm)^3$, using a sequential additive algebraic reconstruction technique. A corresponding 3-D Fourier acquisition would require more than eight hours of acquisition time. Both methods shared the same reconstruction parameters, number of measurements and unknowns for a nearly determined system.

Results

Figures 1(a-c) show axial views of a (linearly interpolated) coronal stack, a PS, and a MS reconstruction, respectively (both after 1500 iterations). The edges between grapefruit wedges are resolved more clearly and uniformly in the MS method, compared to the PS method which to some extent retains (vertical direction) the higher in-plane resolution of the input stacks. The capillaries within the wedges are visualized more clearly using the MS method. The logarithm of the frequency spectrums in Figures 1(d-f) reveals new and uniform content in all directions for the MS reconstruction.

Conclusions

MS competes well with the PS approach and is a better suited SRR technique for isotropic resolution enhancement in MRI. Future work includes a comparison for robustness against motion and inaccurate knowledge of the slice profile.

References

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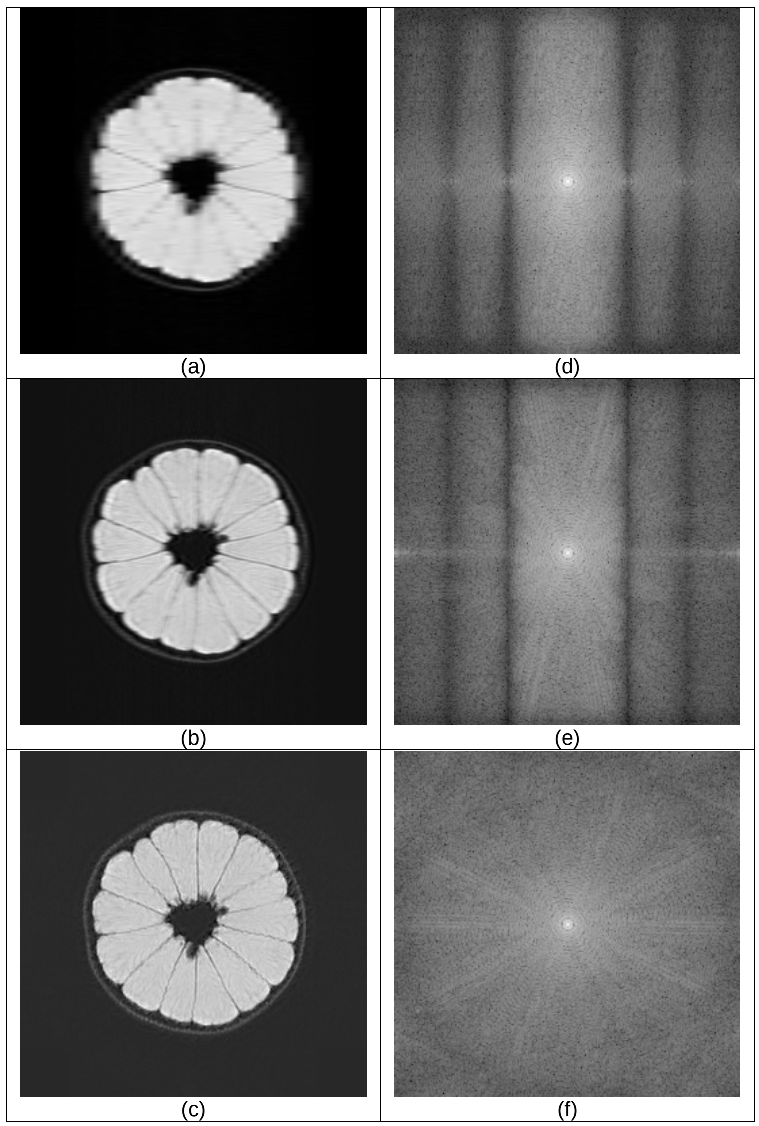

Figure 1 (a) Coronal scan (axial view) acquired with 3.6 mm slice thickness (horizontal axis) and 0.625 mm phase-encoding (vertical axis) pixel size **(b)** Reconstruction of the parallel sub-pixel shift method with $(0.6\ mm)^2$ pixel size **(c)** Reconstruction of the Multi-stack method with $(0.6\ mm)^2$ pixel size **(d)** Coronal scan's frequency spectrum **(e)** Parallel sub-pixel reconstruction's frequency spectrum **(f)** Multi-stack reconstruction's frequency spectrum