Improving Through-Plane Resolution for Multi-Slice Acquisitions

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Target Audience This technique is suggested for clinicians and researches working with multi-slice acquisitions who desire to improve through-plane resolution.

Purpose There has been an increasing trend towards acquiring 3D images in Magnetic Resonance Imaging (MRI), especially for interventional and screening applications [1]. Volumetric 3D imaging does present some difficulties including large volume excitation and increased scan time due to the additional phase encoding (PE) requirement. If the 3D volume is acquired as a multi-slice set of 2D images (which can be acquired faster using an interleaved acquisition) then the resolution in the extra (z) dimension is limited by the slice selection pulse width (on the order of a few mm) [2]. We present here a method for refining 3D multi-slice MRI data to improve resolution in the z-direction.

Additional multi-slice datasets are acquired with z-offsets *nd*/*N* from the initial set, where *d* is the slice thickness, *N* is the total number of datasets to be acquired and *n*=1 to *N*. Figure 1 shows the acquisition strategy for *N*=2. Once the desired number of datasets have been acquired, they are combined into a composite interleaved image *C*. *C* can be considered a blurred image of the true underlying sample, where (in the case of N=2) the blurring kernel is *k:*

$$C = k \otimes I, \qquad k = 1/2\begin{bmatrix}1 & 1\end{bmatrix} \tag{1}$$

where, *I* is a deblurred image. Equation (1) can be rearranged into a matrix equation where *K* is the pseudo-inverse of the Toeplitz matrix for *k*, and then *I* can be determined using:

$$I = KC \tag{2}$$

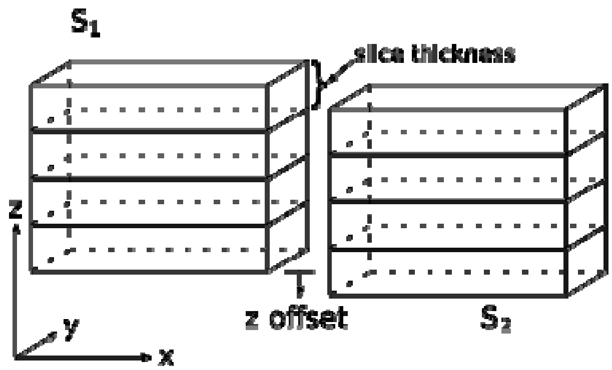

Figure 1 Acquisition strategy for z-deblurring. A second dataset S_2 is acquired at an offset of *d*/2 from the first dataset S_1. *d* is the slice thickness.

Methods The feasibility of this technique was tested using simulated data and a set of real data. The simulated data was created by re-binning averages along the vertical direction of a sample image (the brain in Figure 2a). The original image size was 256x256 and it was re-binned to two staggered 32x256 low resolution images, S_1 and S_2. Additional random noise was added to S_1 and S_2. These component images are interleaved to form the blurred composite image *C* which can then be deblurred via Equation (2). The real data consisted of two sets of 46 slice 512x512 datasets of a phantom obtained on a 1.5T GE scanner.

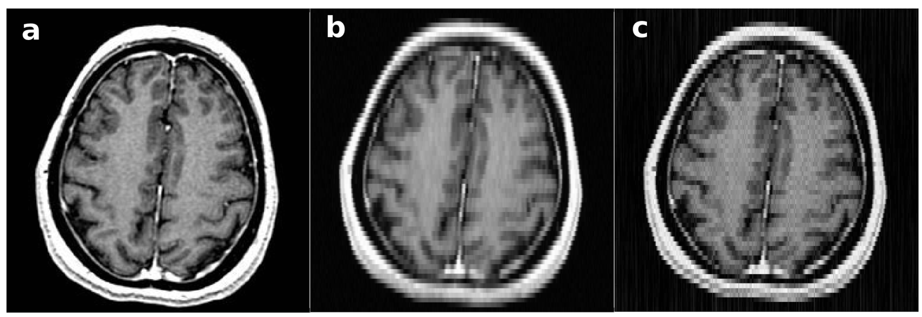

Figure 2 (**a**) High resolution reference image (256x256). (**b**) The blurred interleaved image C (64x256). (**c**) the resulting image after deblurring (64x256).

Results Fig. 2 shows results for the simulated data with *N*=2. The proposed technique is able to restore some of the underlying resolution with minimal adverse effects. Figure 3 displays results from the real data (again *N*=2). In this case, there is no high resolution reference image for comparison, but it can easily be seen that there is an improvement in resolution after deblurring. Unfortunately, there is some residual streaking artifact that must be reduced before the technique will be clinically useful. It is possible that additional interleaves may reduce this problem.

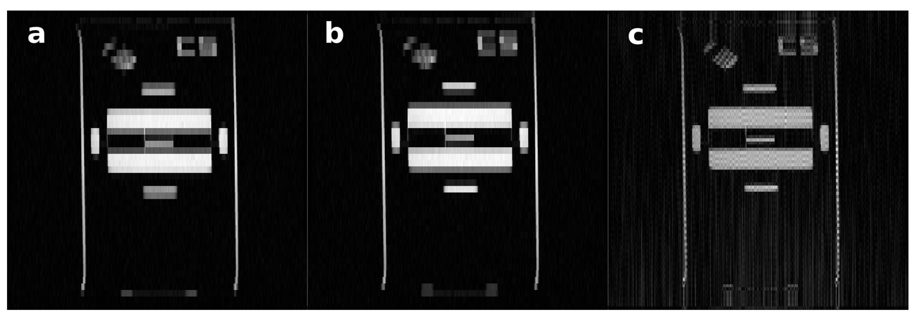

Figure 3 (a) and (b) the blurred staggered images S1 and S2, respectively (46x512). (c) The resulting image after deblurring (92x512). Resolution has improved on fine structures in the upper region of the image.

Discussion A technique for improving resolution in z-direction of multi-slice acquisitions is presented. The technique can be performed on any scanner and can be scaled to achieve the desired degree of refinement.

References

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