Improved PropellerTranslation Correction

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Introduction

Propeller reconstruction corrects for rigid body motion in-plane by comparing redundant data collected at the center of *k*-space where blades overlap. Each blade is a phase-encoded FSE train; blades are rotated to fill in *k*-space. Translation in image space is equivalent to a phase roll in *k*-space, so the relative phases of *k*-space data correspond to patient translation between blade acquisitions. If $f_{shift}(\mathbf{x}) = f_{ref}(\mathbf{x}+\Delta\mathbf{x})$ then *k*-space data has a phase roll $\hat{f}_{shift}(\mathbf{k}) = \hat{f}_{ref}(\mathbf{k})e^{i\mathbf{k}\bullet\Delta\mathbf{x}}$ Each blade's shift is at the peak signal of the convolution of it's low frequency image against a low frequency reference image[1]. By working with each blade's phase data we reduce gridding errors and transform the smooth convolution into an approximate δ, as shown in Figure 4.

$$convolution: \left(f_{shift} * conj\ f_{ref}\right)(\mathbf{x}) = \Im^{-1}\left[\Im f_{shift}\ conj\left(\Im f_{ref}\right)\right](\mathbf{x}) \qquad approx\ \delta: \delta(\mathbf{x}-\Delta\mathbf{x}) = \left[e^{i\mathbf{k}\bullet\Delta\mathbf{x}}\right]^{\vee}(\mathbf{x}) = \Im^{-1}\left[\frac{\Im f_{shift}\ conj\left(\Im f_{ref}\right)}{\left|\Im\hat{f}_{shift}\ conj\left(\Im f_{ref}\right)\right|}\right](\mathbf{x})$$

Methods

Using only the phase of *k*-space data reduces the dynamic range of the data to be gridded and therefore is less demanding of the gridding method. We consider a standard MR "gridding" technique, but the premise is the same for virtually any interpolation or data fitting technique requiring smooth derivatives in the measured data[2]. Gridding the very center of *k*-space is difficult because values jump drastically, and not always smoothly. Notice disparate dynamic ranges and discontinuous first derivative at "DC" shown in Figure 1. The "DC" data point completely overrides all of its nearest neighbors, resulting in radial symmetry at the very center of *k*-space for each gridded blade, as shown in Figure 2. Phase data is more accurately gridded and emphasizes higher frequencies, sharpening the peak as shown in Figure 4.

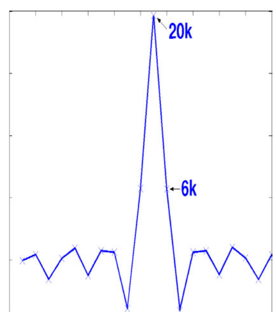


Figure 1 (above) Real part of center column.

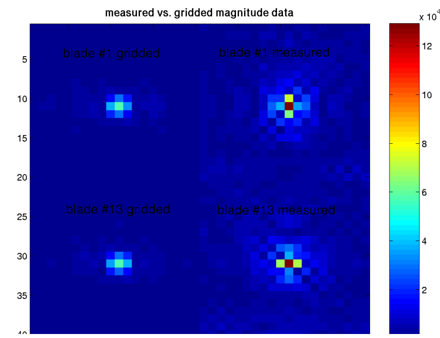


Figure 2 (above) Magnitude of k-space centers for orthogonal blades. Left-gridded; right-measured.

Another precaution against gridding errors is Fourier upsampling (zero-padding) in each direction prior to gridding. 4x upsampling is sufficient to minimize gridding errors and yields comparable results to evaluating the slow Fourier transform.

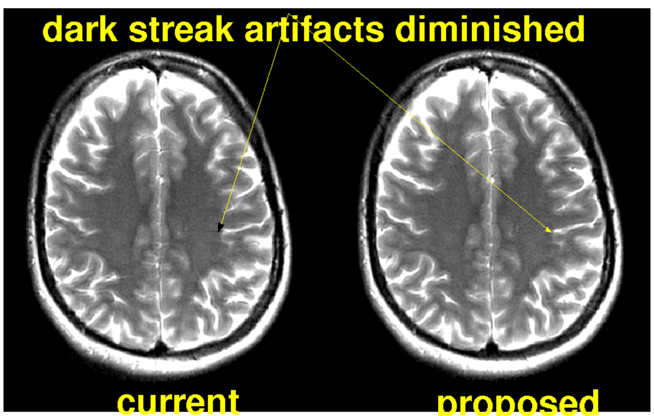
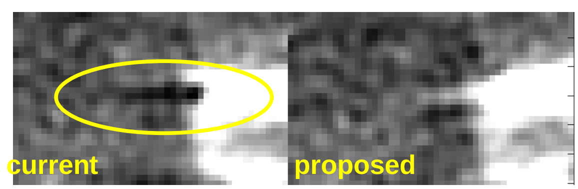


Figure 3. (left) comparison T2 images. (right) blow-up of artifact indicated with arrows.



Conclusion

Reducing gridding errors is crucial for motion correction in Propeller. Redundant data at the center of *k*-space represents low frequencies in the image, but is itself highly oscillatory and therefore difficult to grid. Removing magnitude information high-pass filters the convolution, sharpening it into a δ function. Working with phase data may also serve to minimize relaxation effects. Fine streak artifacts have been removed from clinical Propeller images, as shown in Figure 3.

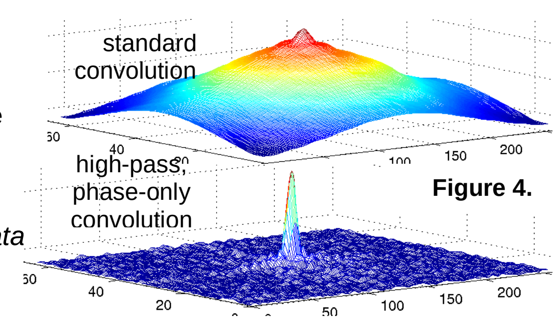


Figure 4.

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Bibliography

[1] Pipe, JG. *MRM* **42**, pp. 963-969, (1999).
[2] Atkinson, "Elementary Numerical Analysis."