Motion Artifact Correction with MOJITO: practical implications

C. A. Bookwalter[1], M. A. Griswold[1], and J. L. Duerk[1]
[1]Case Western Reserve University, Cleveland, OH, United States

Introduction: Correction of 2D rigid body translational motion using phase differences at trajectory intersections, a method we have called Multiple Overlapping k-space Junctions for Investigating Translating Objects (MOJITO) [1], is an efficient self-navigating motion correction method in MRI. This study, investigates the performance of MOJITO in the presence of confounding factors such as noise and field inhomogeneities when gridded BOWTIE [2] trajectory intersections are used.

Methods: Calculated phase differences (Δφ) and known k-space locations (k_x and k_y) are used to calculate a time-dependent representation of motion (Δx and Δy) occurring throughout a BOWTIE acquisition using

$$\Delta\varphi = \Delta x k_x + \Delta y k_y. \qquad (1)$$

In this study, a Shepp-Logan phantom was resampled with a non-uniform FFT algorithm [3] to obtain the desired BOWTIE k-space data (detail shown in Fig. 1a). To create exact intersections, the nearest rectilinear point was gridded (using GRAPPA Operator Gridding: GROG [4]) to the nearest radial point k-location for each radial point used in Eqn. (1). The rectilinear points (white circles, Fig. 1a) are reference data assumed to be acquired without motion.

To examine the performance of MOJITO in the presence of noise, Eqn. (1) was solved using several combinations of intersections. Each intersection consisted of data from eight coils. A pair of intersections at $k_x = \pm 5$ (green circles, Fig. 1a), a pair of intersections at $k_x = \pm 1$ (red circles, Fig. 1a), 40 intersections between $k_x = \pm 5$ (green, red, and black circles, Fig. 1a, oversampled by a factor of 4 in the k_x direction) per PE line were used to solve for Δx and Δy. Additionally, the weighted least squares (WLS) version was solved using the same 40 intersections. For reference, the exact 40 intersections (no gridding) were also used to compare the effect of moving rectilinear points to radial points (i.e., the effect of GROG). Residual difference was calculated over 50 repetitions for several noise levels.

Off-resonance simulations were performed using the field map shown in Figure 1b. Simulated exact intersections with no noise were used to eliminate the effect of gridding and noise. The field map was scaled to different levels of peak field inhomogeneity. Residual difference between simulated and calculated object shifts was determined.

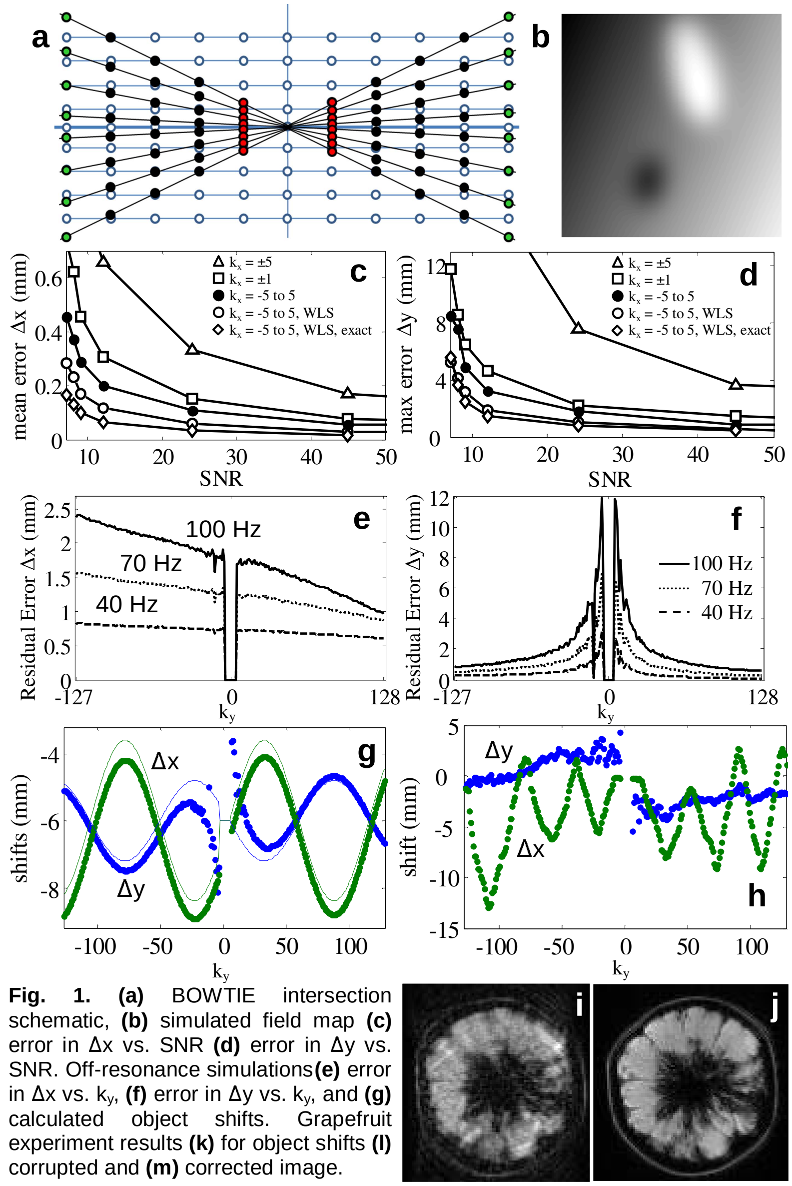

Fig. 1. (a) BOWTIE intersection schematic, **(b)** simulated field map **(c)** error in Δx vs. SNR **(d)** error in Δy vs. SNR. Off-resonance simulations **(e)** error in Δx vs. k_y, **(f)** error in Δy vs. k_y, and **(g)** calculated object shifts. Grapefruit experiment results **(k)** for object shifts **(l)** corrupted and **(m)** corrected image.

Actual experiments were performed to validate the simulations: a grapefruit was moved in the x-direction followed by estimation of object shifts. K-space data was corrected using the algorithm estimated Δx, reconstructed, and compared to the uncorrected image.

Results: Figure 1c and d show the residual error for the noise simulations. Notice that the error in Δy is larger than the error in Δx, but both achieve an accuracy of 1 mm at an SNR of 12 using 40 intersection and a WLS solution to Eqn. (1) (open circles, Figures 1c and d). Figures 1e and f show the residual error for Δx and Δy, respectively, for increasing levels of peak field inhomogeneity (40, 70, and 100 Hz). Figure 1g shows the detected (dots) and simulated (lines) motion detected in the presence of 70 Hz peak field inhomogeneity. Finally, Figures h-j show the detected object shifts, the corrupted image and corrected image for the phantom experiment.

Discussion and Conclusions: Unlike conventional navigator techniques, MOJITO provides motion artifact correction without the loss of efficiency associated with repetitions of portions of k-space. Noise simulations showed that a reasonable SNR was sufficient for 1 mm accuracy. However, off-resonance simulations showed a drift and offset error in Δx and a discontinuity in Δy. The error increased with increasing peak field inhomogeneity. Phantom data matched simulation results where Δx detected with good fidelity, while Δy demonstrated a discontinuity. The image corrected only with calculated Δx showed excellent correction for motion in the x-direction. This work is the first systematic demonstration and analysis of MOJITO in the presence noise and off-resonance effects. The MOJITO motion artifact correction method will afford new efficiency in correcting 2D rigid body translational motion.

References: **[1]** Bookwalter, et al., ISMRM 2007, #3425, **[2]** Bookwalter, et al., ISMRM 2006, #2439, **[3]** Sarty, et al., MRM, 45(5) : 908-915 (2001), **[4]** Seiberlich, et al., ESMRMB 2006, #300.

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