Rotation Correction with Self-Navigated MRI

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INTRODUCTION

Segmented sequences, such as turbo-spin-echo (TSE) sequences, measure multiple lines of k-space with a single excitation. Since k-space is acquired over time in a segmented fashion, object rotation must be considered in the image reconstruction. Previous methods to detect rotation of segmented data typically require prior patient preparation such as the application of spatial-frequency tuned markers(1), the acquisition of additional navigator data such as orbital/spherical navigators(2,3) or non-Cartesian sampling methods such as PROPELLER(4). The proposed technique compares adjacent sets of measurement lines in Cartesian k-space to detect and quantify object rotation. Because the proposed technique makes use of correlations between adjacent data sets, we greatly reduce the total amount of additional data required to quantify object rotations.

THEORY

Consider an object described by a function $m(x,y)$ and Fourier transform $M(k_x,k_y)$. The discrete k-space data sampled by the Lth echotrain of a TSE sequence can be written:

$$M_L(n,m) = \sum_{j'=0}^{N-1} \sum_{j=0}^{N_e-1} M(n\Delta k_x, m\Delta k_y)\delta(m-L-jN_{et})\delta(n-j') \qquad (1)$$

To find the amount of object rotation between two adjacent echotrains, $M_L(n,m)$ and $M_{(L+1)}(n,m)$, we first counter rotate $M_{(L+1)}(n,m)$ by a test angle ϕ and then re-grid the data to form $M_{(L+1)\phi}(n,m)$. The data from the two echotrains are then compared with a weighted difference formula:

$$\Delta M_L(\phi) = \frac{1}{N_W} \sum_n \sum_m \left| \frac{\left| M_{(L+1)2\phi}(n,m) \otimes C(m)\right| - \left|M_{L1}(n,m)\right|}{\left|M_{(L+1)2\phi}(n,m) \otimes C(m)\right| + \left|M_{L1}(n,m)\right| + \varepsilon} \cdot W(n,m) \right| \qquad (2)$$

where $C(m)$ is a convolution function to take advantage of correlations between adjacent data sets, $W(n,m)$ is a weighting function to select the k-space points that contain information from both echotrains, N_w is the total number of points selected by $W(n,m)$ and ε is a small constant to prevent a divide by zero. If the rotated object is not angularly symmetric, then the weighted difference function in Eqn. 2 will exhibit a minimum value when the test angle ϕ equals the object rotation.

RESULTS

Figure 1 shows the comparison of adjacent echotrains from an object rotated by 4.6 degrees. The weighted difference in Fig. 1c shows a definite minimum located at 4.6 degrees. The experiment is repeated comparing the second and third echotrains followed by the third and fourth echotrains with similar results. Applying the proposed self-navigating rotation correction to an entire data set is shown in Fig 2 and 3. The difference image comparing the corrected image to the original shows that most of the remaining artifact has a similar intensity to that of the surrounding noise.
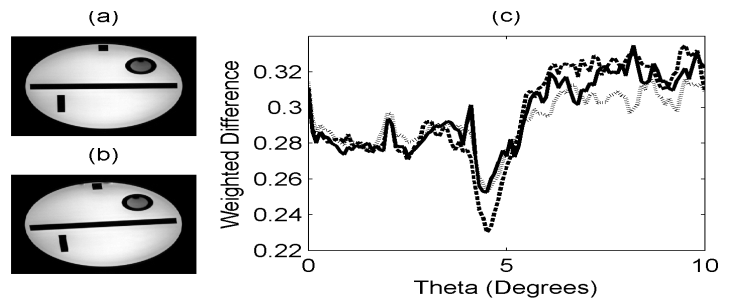
CONCLUSION

This work provides a demonstration that in-plane rotational motion that occurs during the acquisition of MRI data can be quantified using a self-navigation technique. This method can be applied to any segmented sequence that samples k-space in sets of equally spaced lines. It does not require any patient preparation or the acquisition of separate navigator data. The method only requires a slight increase in the field of view along the phase encoding direction, but the amount of increase required is small enough that resolution or total scan time are not significantly affected.

Figure 1: Weighted difference between two adjacent echotrains (c). One echotrain from the object in (a) is compared to an adjacent echotrain from the same object rotated by 4.6° (b). The solid line compares the 1st and 2nd echotrains, the dashed line compares the 2nd and 3rd echotrains and the dotted line compares the 3rd and 4th echotrains.
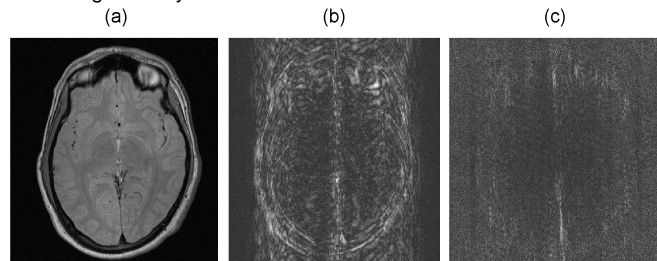

Figure 2: The original artifact free image is shown in (a). The difference image comparing the rotation corrupted and the original image is shown in (b). The difference image comparing the original image and the corrected image is shown in (c).
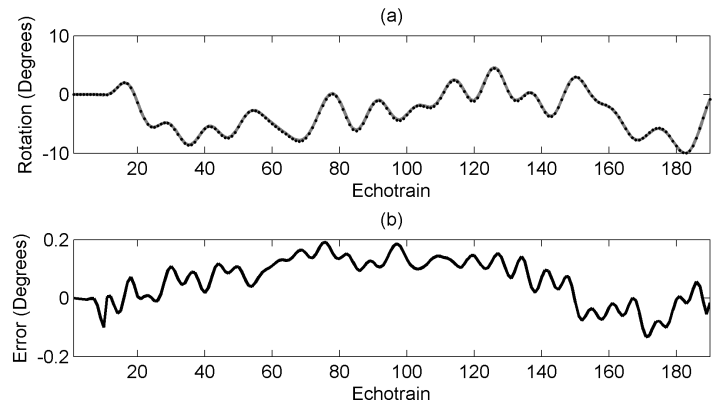

Figure 3: Graph of the actual and detected object rotation (a) and the difference between the two (b). The solid gray line in the top graph is the actual object rotation and the black dots are the detected angles.

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