Correcting for Translational Motion in 3D Projection Reconstruction

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Introduction

Projection reconstruction (PR) has been shown to be more robust to motion artifacts than spin-warp imaging [1]. In PR images are degraded by blurring and streak artifacts instead of ghosting in the presence of motion. The later is due to undersampling the outer portions of *k*-space. In PR the center of *k*-space is acquired in every acquisition. This can be used as an inherent navigator for the detection of motion such as breathing [2]. Most of PR motion correction approaches [3,4,5] address 2D imaging because of the poor sampling efficiency for 3D PR when obeying the Nyquist criterion. However, Block *et al.* [6] demonstrated a 3D projection trajectory, VIPR (Vastly undersampled Isotropic Projection Imaging), which provides high spatial resolution and acceptable artifacts in selected applications despite angular undersampling by factors of 4 to 10 and more. The limiting factor in this acquisition is the SNR and the artifacts introduced from undersampling. Here we investigate a correction scheme for translational motion in three dimensions based on the center of mass approach.

Theory

Gal and Axel [4] describe the center of mass in detail for the 2D case. We extended the scheme for correcting motion in 3D PR. Theoretically, the radial position l_c of the object center of mass in any projection is related to the first moments μ_x, μ_y, and μ_z of the object distribution in the *x*, *y*, and *z* directions by

$$\mu_x \sin\theta \cos\varphi + \mu_y \sin\theta \sin\varphi + \mu_z \cos\theta = l_c(\theta,\varphi)$$

where θ and φ are the polar and azimuthal angles. The image space projection $p(l,\theta,\varphi)$ is calculated by an inverse 1D Fourier transform of the acquired projection to find the measured radial position of the center of mass for each projection angle, $l_{c,m}$. Although μ_x, μ_y, and μ_z can in principle be determined from three orthogonal projections, these quantities were derived from an overdetermined set of multiple projections with singular value decomposition (SVD).

If the object is not moving, the predicted radial position of the center of mass for any projection, $l_{c,p}(\theta,\varphi)$ can be calculated from these moments. Translational motion in the projection direction can then be detected by comparing $l_{c,p}$ and $l_{c,m}$ for each projection. The motion can be corrected by applying a phase correction to the data in *k*-space which results in an shift of the projection in image space.

Fig. 1 The center of mass is established from the first interleave of a 3D PR trajectory.

Methods

A phantom was placed in the scanner and manually moved in the S/I direction. The phantom was moved about 40 pixels in a somewhat periodic fashion to mimick breathing motion. Full echoes with N_r = 256 samples per readout were acquired, which would require over 100,000 projections to satisfy the Nyquist criterion ($\pi/2 x N_r^2$). The data set was undersampled as only 30,000 projections were acquired in 10 interleaves. We assumed no motion in the first interleave, mimicking a short breathhold in the beginning of the scan. Figure 1 shows the trajectory for such an interleaved data set. The projections of the first interleave were evaluated by a SVD algorithm to establish an average estimate for the first moments.

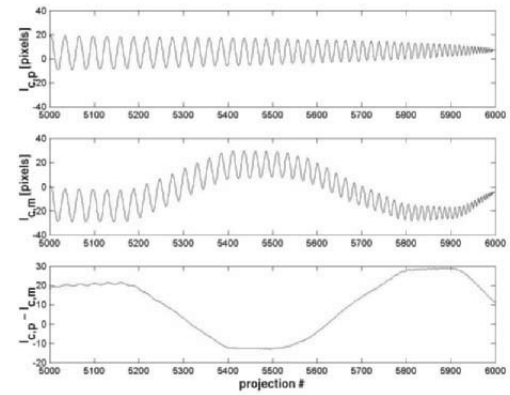

Fig. 2 The predicted radial position $l_{c,p}$ (upper row) and the measured radial position $l_{c,m}$ (middle row) in the presence of motion. The projections are corrected for $l_{c,p}$-$l_{c,m}$ (bottom row) in k-space.

Results and Discussion

Figure 2 shows $l_{c,p}$ and $l_{c,m}$and for the last 1000 projections of the second interleave when the phantom was moved back and forth. Their difference (bottom row) smoothly tracks the motion. Figure 3a shows an uncorrected image from the center of the phantom. The motion occurred mainly in the through-plane direction and slice averaging is quite noticeable. The averaging effects can be mostly removed with the correction method (Figure 3b). Notice the blurring around the corners of the object. Evidently the phantom also rotated around its vertical axis which is not compensated for by the algorithm.

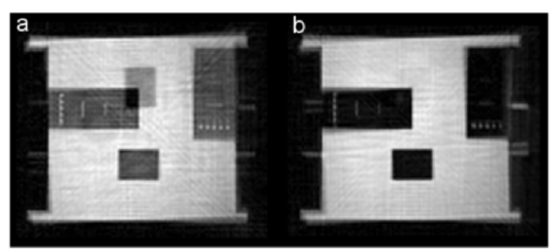

Fig. 3 The uncorrected image (a) shows averaging effects of the motion that mainly occurred through plane. The image quality improves when the correction method is used (b).

Conclusions

We demonstrated a motion correction method for 3D PR that can compensate for translational motion in all directions. This is an extension of most other techniques which typically work in-plane only. At this point we have not included corrections for inter-view motion including scaling, rotational, or non-rigid body motion. In future work, we hope to extend this method for the correction of breathing motion in ECG-gated cardiac imaging.

References

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