Correcting for Translational Motion in 3D Projection Reconstruction: Revisited

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Introduction: The presence of gross body motion or physiological motion such as breathing and cardiac pulsation poses challenges to MRI. Imaging with radial k-space trajectories is often beneficial in the presence of motion. With 2D radial imaging, it has been shown that the information in the projections can be used for detection of motion [1,2], gating of the acquisitions with the cardiac cycle [3], and even correction of the motion [1,2] without the need for additional information such as navigators. Stehning *et al.* [4] have replaced additional navigator pulses with repeated acquisitions of projections along the SI direction for free breathing cardiac imaging with a 3D radial trajectory. In previous work, we have demonstrated the correction for 3D translational motion from such a radial trajectory (VIPR), based on the center of mass (COM) method [5]. Due to imperfections in the actual trajectory caused by eddy currents and gradient imbalances, this implementation required the acquisition of one complete interleaf of motion-free data at the beginning of the scan. Here we investigate an improved correction scheme which omits this requirement, and is therefore self-correcting for translational motion, without penalties in scantime or disturbances of the steady-state.

Methods: In our 3D radial trajectory, the endpoints of the projections lie equally spaced over the surface of a sphere [5]. The criterion used in the estimation of the motion is the position of the radial center of mass in each projection. In a static object, three orthogonal projections can be used to determine the global COM position of the object. Alternatively, a new COM, such as the origin of the coordinate system, can be specified, as was performed in this study. In a moving object, the radial COM location of each projection is shifted by the amount of motion along the axis of that projection (see Fig. 1). Correction is achieved by using the Fourier shift theorem and multiplying the raw k-space data of each projection by the linear phase correction factor needed to shift the radial COM to its correct position. Compensation blips for each gradient axis were added to the VIPR sequence to compensate for trajectory imperfections caused by eddy currents, gradient delays, and other factors [6]. The algorithm and improved sequence were evaluated by placing a spherical phantom with various embedded tissue-mimicking objects in a clinical 3 T scanner (GE Healthcare, Waukesha, WI). The table rocking function was used to slide the phantom back and forth in the scanner throughout the whole acquisition with an amplitude of ±20 mm and a maximum velocity of 15 mm/s. Images were reconstructed with and without the motion correction applied, and a second reference dataset was acquired with a stationary phantom.

Results: Fig. 2 shows the results of the reference scan and of the motion-corrupted scan, with and without correction. The continuous motion in the superior/inferior direction distorts the uncorrected images, and smaller objects are completed blurred out. The corrected images properly display the objects and gridlines despite the severe continuous motion present during the acquisition. The residual artifacts that remain may be due to the fluid in the phantom being constantly in motion.

Conclusions: The corrections applied to the actual trajectory increased the consistency in traversing through the center of k-space in each projection, allowing for proper motion correction on a view-by-view basis without the need for reference or training data. In this exam, motion occurred in the SI direction only, but the trajectory does not have a preferred orientation and similar results would be obtained for translational motion in any direction. In future work, we seek to expand these capabilities to perform navigation and data corrections in 3D to reduce scan time in free-breathing studies in the chest and abdomen. Advantages of this approach over acquisitions with navigator pulses include improved scan efficiency, no distortion of the steady state, direct measurement of the object's motion instead of indirect tracking through the diaphragm position, 3D motion tracking, and subvoxel accuracy of the COM measurement. With the improved data consistency, we will also investigate correction schemes for rotational motion.

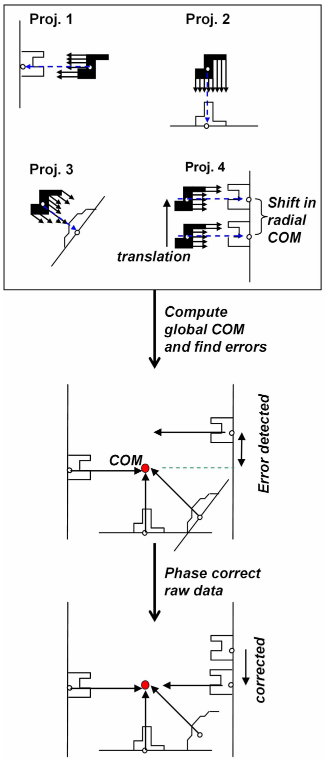

Fig. 1: *Schematic of the motion correction scheme based on COM analysis (shown in 2D).*

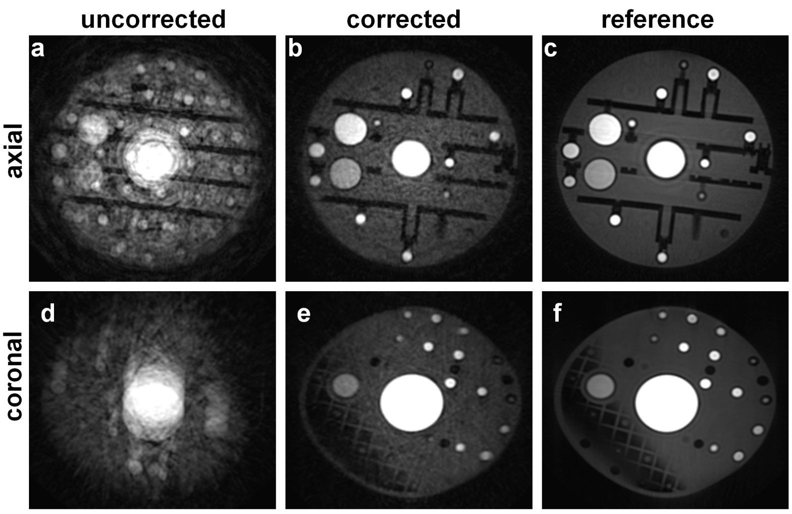

Fig. 2: *Results from VIPR acquisitions in the presence of translational motion in SI: uncorrected (a,d), corrected (b,e), and reference images unaffected by motion (c,f) are shown for a central axial (top row) and coronal (bottom row) slice.*

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