Motion Corrected Radial MP-nRAGE

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TARGET AUDIENCE Researchers and clinicians who need motion robust forms of T1 weighted (T1w) imaging.

PURPOSE Conventional MPRAGE[1] (Magnetization-Prepared Rapid Gradient Echo) T1w acquisitions are highly sensitive to head motion and physiologic motions from flow and eye movements. The PROPELLER technique[2] original introduced for T2 weighted imaging and later modified for T1 FLAIR imaging[3] corrects well for in-plane motion, but not for through plane motion. The aim of this work is to develop a technique for T1w imaging that is (1) less sensitive to motion (2) can detect motion in 3D and finally (3) can retrospectively correct for occasional 3D motions from twitching, swallowing, coughing, or adjusting for comfort.

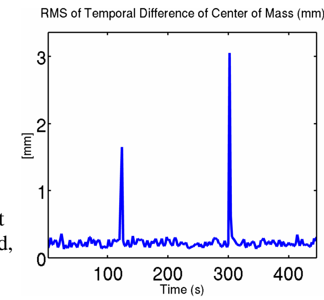

Fig. 1 Motion detection using multichannel center of mass analysis. k-space data is divided into motion-consistent subsets used to form low resolution navigator images and estimate motion parameters

THEORY We will satisfy aim (1) above using the recently introduced MP-nRAGE method[4]. The MP-nRAGE method uses a 3D radial k-space trajectory with inversion recovery preparation pulses. As originally introduced, MP-nRAGE is inherently less sensitive to motion due to the over-sampling of the center of k-space with each radial projection[5]. In this work, we have improved that technique by adding orthogonal k-space projections at the end of every GRE readout block and an optimized angular ordering scheme to allow consecutive sets of motion-consistent data to form navigator images used to co-register the individual undersampled high resolution images within each motion consistent bin. The orthogonal projections allow the coordinates of the center of mass (COM) to be calculated once per inversion (~2s). Although COM analysis can accurately detect and quantify translation,[6] it is insensitive to rotations about the COM. However, a recent work[7] showed that COM analysis can be used to detect rotation when a multi-channel receive coil is used and COM analysis is performed on a coil-by-coil basis. Once motion is detected, the radial k-space projections from MP-nRAGE can be divided into motion-consistent bins and used to form low-resolution navigator images. The navigator images are then co-registered with FSL using a rigid body transformation. High resolution, undersampled images from each motion-consistent bin are then reconstructed and co-registered with the motion parameters determined from the navigator images, resulting in a single image with high SNR and less radial undersampling artifact.

Acquisition note: In order for this method to work, the acquisition is arranged so that the radial k-space projections acquired after each inversion pulse approximately sample the unit sphere evenly. The overall spacing of projections is also intereleaved using a bit-reversed technique between inversions so that projections from consecutive inversion pulses also sample the unit sphere approximately evenly.

METHODS An adult volunteer who was able to remain motionless for extended periods of time was used to demonstrate the proposed method. In one acquisition, the head was immobilized well with foam padding and the volunteer was instructed to remain motionless. In the second experiment, the stabilizing padding was removed and the volunteer was instructed to rotate his head to one side at 2.5 minutes into the scan and back to approximately the starting position at 5.0 minutes. The total scan lasted 7.5 minutes. To determine how the method handles more frequent amounts of motion, we numerically added 9 degrees of rotation at 20s into the scan. Additional parameters include: FOV = 256 mm x 256 mm, slab thickness = 180 mm, acquired resolution = 1.0 mm x 1.0 mm x 1.0 mm, 302 TRs (4.89 ms) starting 20 ms after each inversion, 2.0s between inversion, TE = 1.8 ms. The three orthogonal views were acquired as the 303-305 TR for each inversion.

RESULTS Examples images from the motion free, motion, and motion corrected experiments are shown in Fig. 2. In MP-nRAGE, motion manifests as a blur (Fig 2a,e) instead of ghosting as with a Cartesian based MPRAGE acquisition. The proposed technique reconstructed the motion corrupt data shown in Fig. 1 and Fig 2a,e to produce high quality images (Fig.2c,g) with little motion artifact as evidence in the difference images (Fig 2 k,o) which have been scaled by a factor of 3 to demonstrate the accurate reconstruction of the technique. When additional motion was added to the same data to produce a motion consistent bin as little as 20s, the proposed technique performed nearly as well (Fig. 2 d,h,l,p).

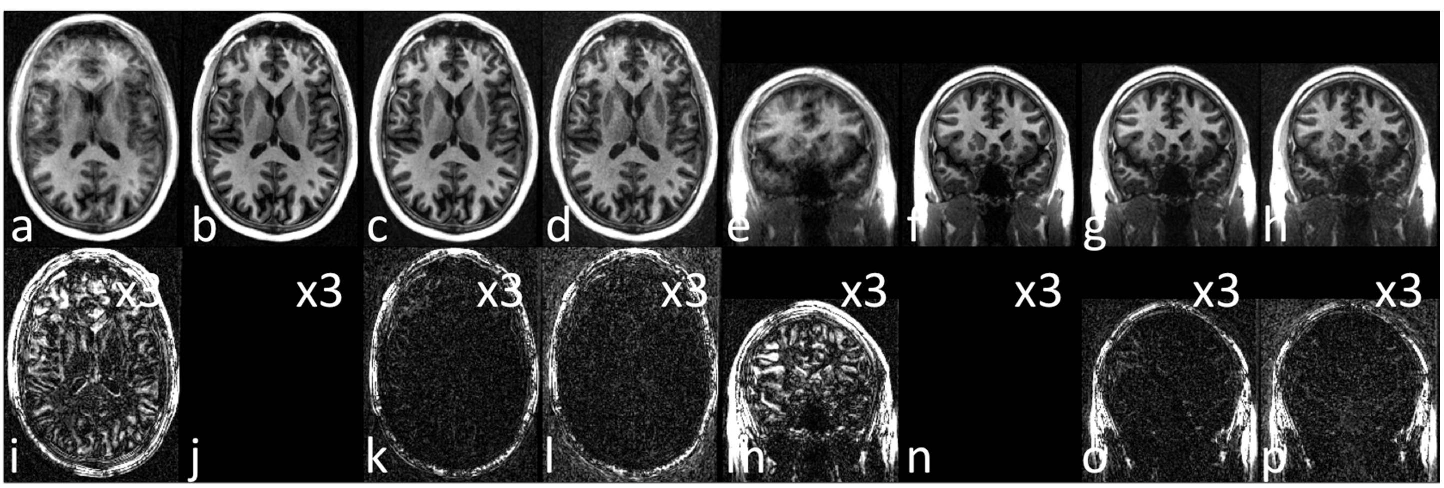

Figure 2: Motion with MP-nRAGE manifests as blurring (a,e) and can be corrected (c,g) using proposed method. In (d,h) 9 degrees of extra rotation was numerically added at a point 20 s into the scan to test the method with more frequent amounts of rotation. A 3mm navigator was still able to correct for almost all motion artifacts. References images (b,f) acquired with stabilization pads in a complicit volunteer are used to form difference images(i-p), which have been scaled by a factor of 3.

DISCUSSION & CONCLUSION In this study, we have successfully demonstrated a new technique to correct for occasional motions in T1w magnetization prepared images. This technique will be useful for studies in less compliant populations including young children, as well as populations that are either older, intellectually impaired, or in pain.

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