Real-Time 3D Motion Correction for High-Resolution MR Imaging of the Larynx

J. K. Barral[1], J. M. Santos[2], E. J. Damrose[3], N. J. Fischbein[3,4], and D. G. Nishimura[5]
[1]Bioengineering, Stanford University, Stanford, CA, United States, [2]Heart Vista, Inc., Los Altos, CA, United States, [3]Otolaryngology, Stanford University, Stanford, CA, United States, [4]Radiology, Stanford University, Stanford, CA, United States, [5]Electrical Engineering, Stanford University, Stanford, CA, United States

Introduction: High-resolution MR imaging requires small voxels and long scan times and is therefore vulnerable to involuntary and physiologic motion. In high-resolution imaging of the larynx, motion poses an even greater challenge than in high-resolution imaging of other body areas because patients often swallow and cough during the scan. To combat all types of motion affecting larynx imaging, we propose a real-time algorithm that integrates different strategies: navigator-based motion correction is used to correct for rigid-body motion, while data corrupted by non-rigid motion are reacquired.

Methods: Algorithm: We implemented our algorithm within RTHawk, a real-time acquisition, control, and reconstruction environment for MRI [1]. A 3D Fast Large Angle Spin Echo (FLASE) sequence was used with a Cartesian readout trajectory and navigators interleaved among the X, Y, and Z axes—i.e., with only one navigator played every TR, either on X, Y, or Z [2]. The order of the phase encodes is described in a table that is loaded on the fly. Figure 1 shows a simplified block diagram of the reconstruction pipeline. Data received from the scanner are separated between image data, which are accumulated until the entire k-space is acquired, and navigator data, which are processed in real time. Data from each coil are processed in parallel and combined using sum-of-squares. The displacements (shifts) are extracted from the navigator data using a Lucas-Kanade algorithm [3]. Based on the effectiveness of the rigid-body motion correction (phase modulation in k-space), a list of encodes to reacquire is computed and sent to the scanner. After rigid-body motion correction, encodes that are most heavily corrupted are reacquired first. At each iteration (pass), an uncorrected image and a motion-corrected image are displayed. The user decides to stop the scan when satisfactory image quality is obtained.

Our algorithm extends the performance of the Diminishing Variance Algorithm (DVA) [4]. In conventional DVA, a histogram of shifts based on navigator data is used to determine which image data to reacquire. These estimated shifts depend on both rigid-body and non-rigid motion. Our algorithm instead analyzes the histogram of errors after rigid-body motion correction to determine which image data to reacquire. This histogram of errors is indicative of the amount of non-rigid motion. Because rigid-body motion correction of the navigator data is performed first, continual bulk motion no longer impedes nor prevents the convergence of the algorithm.

Experiment: Scans were performed on a 1.5T GE scanner using a larynx-dedicated three-coil array [5] and the following parameters: TR/TE = 80/10 ms, FOV = 12 cm, slice thickness = 1.5 mm, matrix size = 256×128×32 (4096 encodes), 192 encodes reacquired per pass. To challenge the method, the volunteer was instructed to swallow and cough intermittently at will, as well as to accentuate motion when the center of k-space was being acquired, which mimics the worst-case scenario that can happen in vivo.

Results and Discussion: Figure 2 shows uncorrected and corrected larynx images after the initial full acquisition and after the fourth pass. Ghosting and blurring artifacts corrupt the initial uncorrected image. Reacquisition is needed to account for the non-rigid, sporadic motion, and ghosting artifacts are greatly reduced once the corrupted encodes are reacquired. Rigid-body motion correction is then needed to correct for bulk motion. In this experiment, four passes were acquired: only 14% of the data had to be reacquired to obtain an image free of motion artifacts.

We demonstrated the benefits of our algorithm for larynx imaging, but the method is general and can be applied to other body areas.

References: [1] Santos, IEEE-EMBS 2:1048-51, 2004 [2] Song, MRM 41:947-953, 1999 [3] Barral, ISMRM Current Concepts of Motion Correction for MRI and MRS Workshop, 2010, p.18 [4] Sachs, MRM 34:412-422, 1995 [5] Barral, ISMRM 2009, p. 1318

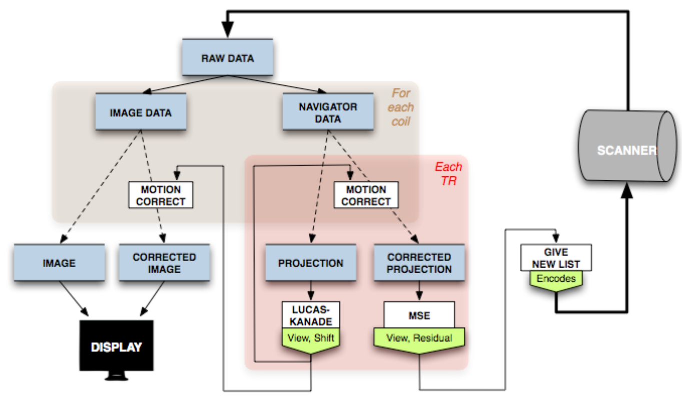

***Figure 1**: Reconstruction pipeline.*

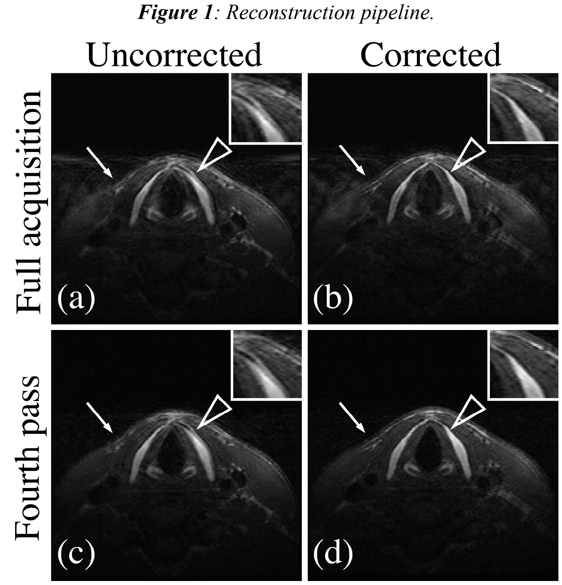

***Figure 2**: Volunteer experiment: axial views of the larynx. Uncorrected (a,c) and rigid-body motion-corrected (b,d) images after the full acquisition (a,b) and the fourth pass (c,d) are shown (resolution = 0.5×1×1.5 mm^3). Sporadic motion results in ghosting artifacts that are greatly reduced after reacquisition of the corresponding encodes. Rigid-body motion correction is necessary to provide a sharp depiction of the skin (arrow) and thyroid cartilage (arrowhead).*