

Motion Artifact Removal by Retrospective Resolution Reduction (MARs): Combination with GRAPPA Acceleration and Clinical Assessment of Image Quality

Candice A. Bookwalter¹, Michael W. Harrell², Nicole Seiberlich³, Smitha Thomas¹, Raj Mohan Paspulati¹, Jeremiah A. Heilman⁴, Mark A. Griswold^{1,3}, and Vikas Gulani^{1,3}

¹Department of Radiology, University Hospitals Case Medical Center/Case Western Reserve University, Cleveland, OH, United States, ²School of Medicine, Case Western Reserve University, Cleveland, OH, United States, ³Department of Biomedical Engineering, Case Western Reserve University, Cleveland, OH, United States, ⁴Quality Electrodynamics, Mayfield Village, OH, United States

Introduction:

Almost every acquisition during a magnetic resonance (MR) abdominal exam requires a breath hold to limit motion. Even with strategies to minimize breath holds (such as parallel imaging), patients are often unable to comply with the entire breath hold. The resulting motion artifacts are usually irreversible, particularly with timed post-contrast studies. There is therefore an open need for a retrospective, robust method for recovering useful images from motion corrupted data. The Motion Artifact Removal by Retrospective Resolution Reduction (MARs) [1] method was described for motion correction, in which a GRAPPA navigator based motion detection scheme [2,3] was combined with a centric acquisition so that a transition to motion (when a breath hold fails) can be detected, and motion corrupted data retrospectively rejected. However, MARs was initially demonstrated on fully sampled data and did not take advantage of the acceleration properties of parallel imaging. Here, we extend the MARs method in combination with standard parallel imaging undersampling using patient data. Second, the underlying assumption with MARs is that low resolution but motion free images are preferable to higher resolution images with motion artifact. We tested this hypothesis by comparing uncorrected and MARs corrected images in a radiologist reader study on 25 patients, using a two alternate forced choice (2AFC) ratings.

Methods:

Patient Data – The study is IRB compliant. Informed written consent was obtained. Fully-sampled centric ordered 3D VIBE datasets of the abdomen were obtained for 25 patients undergoing abdominal exams with contrast on a Siemens Avanto 1.5T scanner. The VIBE sequence was chosen because it is widely utilized for the pre- and post-contrast T₁-weighted imaging series in abdominal imaging. Imaging parameters were FA=25°, TR=7.68ms, TE=2.38ms, ST=3mm, BW=490Hz/Px, and phase partial Fourier=7/8. Total acquisition time was 23 seconds. The collected data were fully sampled to allow comparisons between fully sampled and undersampled data. Multiple data sets were collected for each subject such that each patient resumed breathing after approximately 30%, 60%, and 100% of the data were acquired. For five patients, respiratory bellows data was also acquired for reference. A total of 39 data sets were determined to have a failed breath hold (as instructed).

Collected data sets were undersampled by a factor of two and GRAPPA navigators were calculated (40 ACS lines, 4x5 GRAPPA kernel) for the remaining lines. MARs was then applied by calculating the correlation coefficient between all PE lines and their corresponding GRAPPA navigators. The transition from uncorrected to motion corrupted data was defined as a 0.3 fractional change in correlation coefficient. PE lines after the detected transition were replaced with zeros and images were reconstructed using standard techniques.

Image Ratings - The tradeoff between artifacts due to motion and loss of information due to line removal and its impact on image quality was assessed by a 2AFC paradigm [4,5] ratings. Two radiologists were presented with the uncorrected and MARs corrected images side by side for patient data compliant with approximately 30 and 60% breath holds for a total of 39 image pairs and instructed to select the higher quality image.

Results:

Figure 1 shows typical results for correlation coefficients (blue) for undersampled data with corresponding respiratory bellows data (red). As expected, there is a sharp decrease in correlation coefficients at the transition from breath hold to free breathing corresponding well with bellows data.

Two radiologists showed a preference for the MARs corrected image on average 80% of the time. More specifically, the first rater preferred the MARs corrected images 86% of the time (32/39) and the second rater 74% of the time (29/39). The inter-rater agreement was good with an intraclass correlation coefficient of 0.486 and a kappa of 0.478 [6]. The images shown in Figures 2b (uncorrected) and 2c (MARs corrected) are typical of those presented for 2AFC rating.

Discussion:

This work shows that MARs can be used retrospectively to remove the effect of patient motion in the presence of parallel imaging time acceleration by eliminating corrupted data. Patient data demonstrate excellent detection of motion corrupted lines in the undersampled case. The core assumption that an image with lower resolution but without motion artifacts interferes less with image interpretation compared to a higher resolution image which is corrupted by motion artifact, is supported by the 2AFC ratings which demonstrate preference for the MARs image on average 80% of the time with good inter-rater correlation. The data imply that MARs may be implemented with standard clinical sequences to retrospectively reject motion corrupted data, combined with parallel imaging for image acceleration, and that the resulting image quality is preferred by radiologists to motion corrupted but higher resolution images.

References: [1] Bookwalter et. al, Proc. of ISMRM 2011, 4603. [2] Bydder et. al, MRM, 2003; 49(3):493-500. [3] Roder et. al., Proc of ISMRM 2008, 1291. [4] Chapman et al, Comp Biom Res, 1999;32(6):530-556. [5] Hoppin et al, IEEE TMI, 2002;21(5):441-449. [6] Landis et.al., Biometrics, 33;1: 159-174.

Acknowledgements: This work is supported in part by the RSNA Peggy J. Fritzsche, MD Research Resident Grant, NIH/NIBIB 5K99EB011527, NIH 1KL2RR024990, and Siemens Medical Solutions.

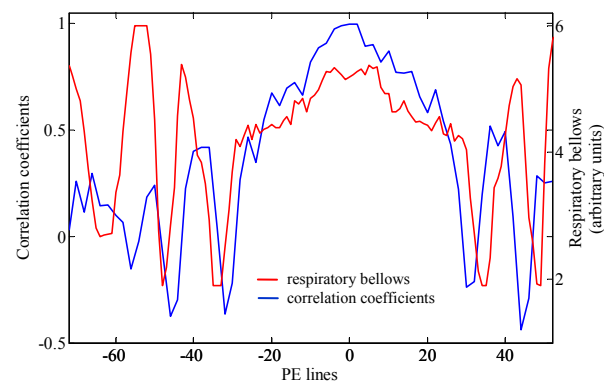


Figure 1: Calculated correlation coefficients (blue) for undersampled PE lines and corresponding GRAPPA navigator. Respiratory bellows data is shown in red for reference.

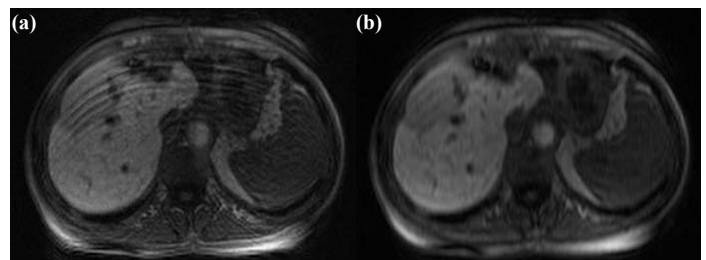


Figure 2: Motion corrupted (a) and MARs corrected images (b) for approximately a 50% breath hold. This patient is status post partial liver resection and post ablation.