Less can be More: Reduction of Motion Artifacts by Ignoring Parts of the Acquired Dataset

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Introduction: High resolution MR imaging of the carotids is an interesting technique for plaque characterization but image quality can be compromised by motion artifacts. Effects of quasi-periodic motion (breathing, pulsation) can be reduced by gated acquisition. Coping with non-periodic motion (e.g. swallowing) is still often challenging in clinical practice and is considered as a major factor that contributes to the overall 20% failure rate in clinical scans. We present a method to reduce the effects of sudden, non-periodic motion by exploiting data redundancy which is usually present in parallel imaging. with multiple receive coils.

Methods: Our approach essentially consists of two steps: 1. Detect retrospectively and automatically which part of the acquired k-space dataset is corrupted by motion and 2. Reconstruct an image using only that part of the dataset that is not affected by motion.

We assume that a Cartesian acquisition scheme is used and that the data are acquired in sets of evenly spaced k-space lines (interleaves). This is common for fast acquisitions like TSE, TFE, EPI, etc. Only motion between interleaves is considered. I.e., the whole set of k-space lines belonging to a particular interleave is either accepted or rejected by the motion detection. According to the motion state, a sub-set of data which is free of motion is selected from the whole acquired data for reconstruction.

The first step, motion detection, can be accomplished in several ways: a) by an external device which detects motion [1], b) by a navigator profile [2, 3], or c) by a search for self-consistent sub-sets of data. In the following, we focus on the third approach and use a navigator profile as standard of reference.

We detected the interleaves which were disturbed by swallowing by an iterative self-consistency analysis (Fig. 2): First, an image is reconstructed from all data. Then, simulated data are computed from this image and compared to the measured data. That interleave which has the highest inconsistency is removed from the dataset, a new image is reconstructed from the remaining dataset, and the inconsistency is checked again using this image, etc. In this way, corrupted data are identified and excluded from the reconstruction.

The second step, image reconstruction, is similar to a SENSE reconstruction [4]: First, the data of each selected interleave and coil are Fourier-transformed individually. This results in images with a strongly reduced field of view. Then, the full field of view image is reconstructed from the reduced field of view images using the coil sensitivity maps. In this step, a specific phase correction takes care of the different k-space positions belonging to the different interleaves.

The new artifact reduction method, which can be performed as a post-processing step, was tested for TSE imaging in phantom and in vivo volunteer scans.

Experimental: As an example, we used the method to reduce artifacts induced by swallowing in imaging of the carotids. 2D TSE acquisitions (TE 70 ms / TR 2000 ms) were performed with a flexible 6-element head/neck coil on a few volunteers. The full k-space was sampled with 256 phase encoding steps, using 16 interleaves (TSE-factor of 16). In addition to the imaging data, one orbital navigator profile [2] was acquired as the first echo of each TSE train (interleave) to directly identify motion. During data acquisition the volunteer deliberately swallowed once.

Results and Discussion: Auto-navigation based on self-consistency was able to identify the interleaves affected by motion (see Fig. 2). The same interleaves were identified using the orbital navigator data.

Fig. 3 shows a comparison of a reconstruction using all data and a reconstruction using only the sub-set of data. The zoom of the carotid clearly shows an improved quality in the image reconstructed from the reduced dataset. It is noteworthy that an artifact that represents similar signal patterns as calcium deposition can be identified on the original image, but is completely removed on the optimally reconstructed image (Arrows).

The reconstruction method is applicable to any acquisition which has redundancy in the dataset. This is commonly the case in parallel imaging, when a reduction factor is used which is less than the number of coils employed.

Conclusion: The presented method can reduce artifacts caused by sudden, non-periodic motion. It can be applied retrospectively without any navigator information. However, if navigator data are available they can be used to simplify the motion detection step.

References : [1] Chan et al., MRI 29: 211-216,2009; [2] Fu et al., MRM 34: 746-753, 1995; [3] Crowe, et al., MRI 22:583 - 588, 2005; [4] Pruessmann et al., MRM 42: 952-956, 1999

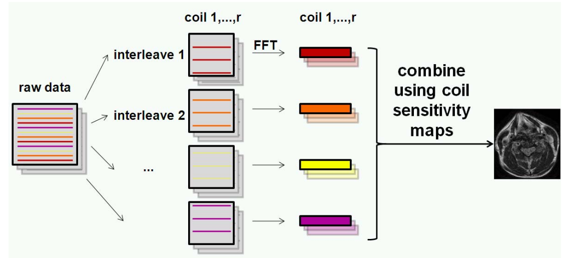

Fig. 1: Schematic representation of the data flow in the reconstruction algorithm. An arbitrary combination of data from different interleaves and coils can be selected as long as the resulting system of equations is still over determined.

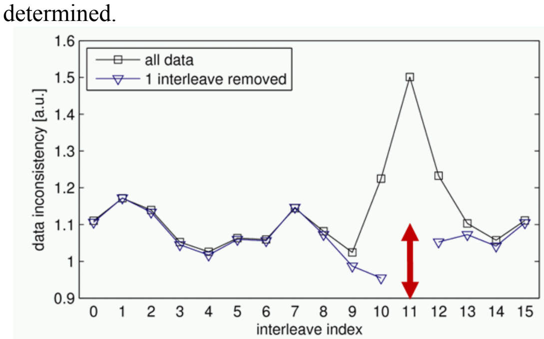

Fig. 2: Results of consistency analysis (1st iteration): The horizontal axis shows the interleave index. The vertical axis shows the inconsistency between acquired data and data simulated from an image which was reconstructed from the full or a reduced dataset (here: interleave #11 removed), respectively. The arrow indicates the corrupted data detected by the orbital navigator.

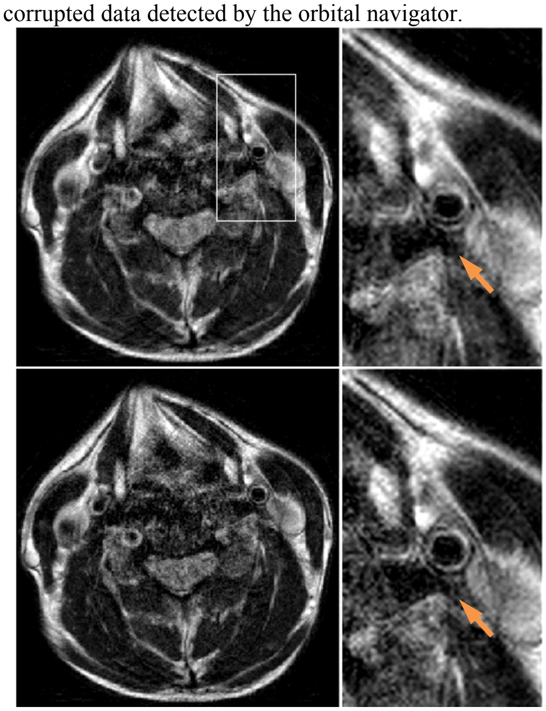

Fig. 3: Comparison of reconstructed images using all data (top) and using a reduced number of interleaves (bottom). Image quality is improved by ignoring the data acquired during the motion phase. An artifact which represents similar signal patterns as calcium deposition is removed on the optimally reconstructed image (Arrows).