Efficient motion artifact reduction technique based on post-processing

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Introduction: Patient motion during MR scans remains as one of the major problems. While advanced correction methods using for example navigators have been developed, many clinical institutions do not have these features readily available. Several post-processing motion correction techniques have previously been introduced to reduce motion artifacts [1-3]. These methods rely on perturbing the k-space data acquired continuously to find a motion-less image. Metrics such as the entropy of the image are typically used to quantify the amount of motion present. These techniques, which do not need any a priori information, have been shown to reduce translational motion artifacts effectively. One of the main limitations of these techniques however is the long processing time required to find the optimal image. A huge number of Fourier Transform (FT) steps are required since k-space re-phasing is iteratively applied and for each k-space correction, calculation of the metric in the image space needs to be performed. Thus, most of the processing time is spent on the FT operation and in calculating the image metric. Here, we propose a simple method to reduce this total processing time for metric based motion correction techniques. The target is for two dimensional applications where motion artifacts are dominant in the phase encoded direction but extensions for correcting different motion components and also for three dimensional k-space data acquisition methods can be readily achieved.

Methods and Theory: An outline of the various modification steps that were implemented is presented here. First, to correct for phase encode direction motion in the k-space data set, rather than applying the phase corresponding to the various displacements and finding the displacement which achieves the best image metric, we use convex optimization to find the optimal phase. This approach can be used because the relation between optimal phase and metric value is almost convex. Therefore, any convex optimization strategy can be used to find optimal phase that makes minimum metric value and the corresponding displacement can be extracted from the phase.

Secondly, by using the separability property of two dimensional FT we can reduce the total number of FT operations by about 60% if we apply the phase correction after FT is performed in the readout direction. In this case, since applying a phase to the phase encoded lines does not affect the readout direction k-space data, FT of the readout direction lines to the image space is by default performed. By using this method, the two dimensional FT operations are all reduced to one dimensional operations. If extended to three dimensional FT acquisitions, we can expect the reduction of approximately 30% of FT calculations needed.

Thirdly, instead of using the entropy as the image metric, we used the sum of pixel intensities in the image as an alternative metric. The entropy metric and sum of pixel intensity metric have similar characteristics in that minimizing one of them equally minimizes the other. In regards to calculation time however, the sum of intensity metric significantly reduces the overall computation time compared to entropy calculations to approximately 50%.

Finally, with this modified algorithm, we combined partial k-space reconstruction using the POCS method to further reduce the total processing time. The method adopted into the POCS routine is simple. If we have no motion in certain parts of k-space, we can construct a motion-free image from that part using partial reconstruction. As motion itself can occur randomly, it is not obvious which lines of k-space are actually motion-free. Therefore, in this study we divided the whole k-space into two parts, namely the upper and the lower partial k-space segments. From these two segments, we can detect which part has less motion by using the above metrics. Taking the less corrupted segment, we perform the motion correction algorithm and reconstruct the image from the partially corrected k-space data. By reconstructing on a partial data set, the overall computation time can be further reduced.

Search strategy was used similar to the method outlined in [3] by starting from center of k-space to outward by first correcting for blocks of phase encoding lines and iteratively reducing the block size by half until the block has only one phase encoding line. To test our approach, we used simulated sagittal head image data by applying aperiodic motion in phase encode direction. In vivo data were also collected where the volunteer was asked to produce small random motion of the size below 0.5 cm. Processing times savings were recorded for the various routines mentioned above. MATLAB R2007a on an Intel dual core processor (2.13GHz) was used for the implementation.

Results: In Fig. 1, resulting images using the proposed method (c) and conventional post-processing method (d) are given showing similar results (entropy of b: 861.5, entropy of c: 806.2, entropy of d: 809.3). Fig. 2 shows in vivo results obtained before and after applying our proposed method from a subject with voluntary motion. The proposed method shows region where motion artifact is reduced (indicated by the arrow). Table 1 summarizes total processing time for each reduction method applied to data of Figure 1 and 2. Processing time is reduced to as short as 15% of the original method's processing time.

Image size		Separated 2DFT	Metric used	Partial recon	Process time (s)	Time reduction (%)
224x200 size (Fig 1)	1	X	Entropy	X	65	100
	2	O	Entropy	X	59	91
	3	X	Pixel sum	X	35	54
	4	O	Pixel sum	X	29	45
	5	O	Pixel sum	O	9	14
512x408 size (Fig 2)	1	X	Entropy	X	719	100
	2	O	Entropy	X	654	91
	3	X	Pixel sum	X	415	58
	4	O	Pixel sum	X	350	49
	5	O	Pixel sum	O	164	23

Table 1: Total processing time for various methods with different image size.

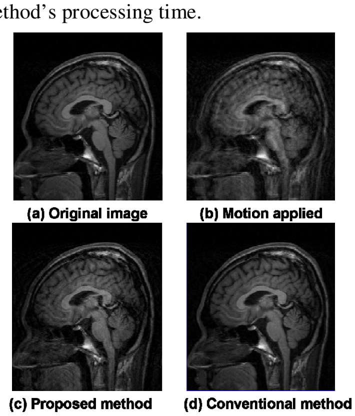

Figure 1: Result of simulated data.

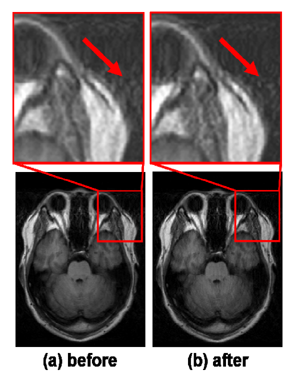

Figure 2: Result of in vivo data using proposed method.

Conclusion: We have presented a simple method based on post-processing to reduce motion artifacts. The primary advantage of this approach is in its computational speed, which reduces processing time to as short as 15% of conventional schemes. The primary usefulness of this approach would be on post-processing correction of large 2D image sizes or with 3DFT k-space acquisition data sets. It can be useful when alternative methods such as navigators are not available or even be used together with them to further reduce motion degraded artifacts.

References

[1] D. Atkinson, et al., IEEE Trans. Med. Imag. 16:903-910, 1997 [2] P. McGee, et al., MRM, 11:174-181, 2000 [3] A. Manduca, et al., Radiol., 215:904-909, 2000