Enhanced Motion Correction Combining PROPELLER and Parallel Imaging

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Introduction: PROPELLER MRI [1] uses rotating sampling strips to correct rigid motion artifacts between blades. However, PROPELLER cannot correct motion that occurs within one blade and performs ineffectively in correcting non-rigid motion artifacts caused by through-plane motion or respiratory motion etc. Parallel Imaging (PI) techniques have been mainly used to speed up the imaging time by under-sampling the data so that the motion artifacts can be frozen. However, parallel imaging techniques can also be used to detect and correct motion artifacts instead of preventing them [2]. In our study we proposed to combine PI with PROPELLER to detect and eliminate corrupt k-space lines either within one blade or between blades by using the redundancy data in multi-coil.

Methods: Instead of accelerating MRI acquisition time, the data in each coil is fully sampled. Then they are regenerated in k-space by using CG-PROPELLER method. Consistency information is incorporated in every k-space line during the process of CG-PROPELLER because CG uses sensitivity information in image domain. The corrupt lines due to motion can then be detected by comparing the difference between the regenerated and original lines [3]. The schematic diagram of the proposed method is shown in Fig.1. Let $S^o_{b,c}(k_x,k_y)$ be the original Fourier data sampled at points (k_x,k_y), acquired from b^{th} blade in c^{th} coil in an array of N coils (here it is 2 for simplicity) with M blades in each coil.

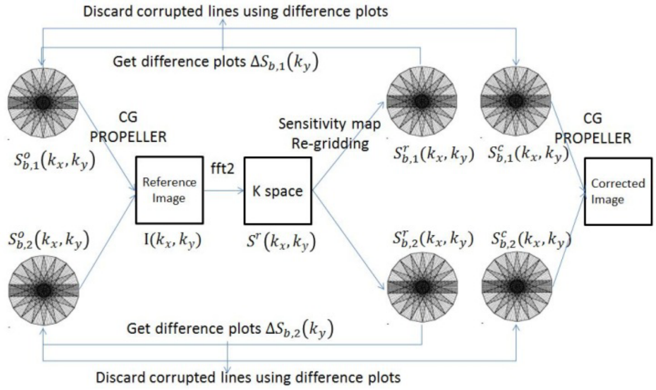

Fig.1 Schematic diagram of the proposed motion correction method

The correction steps are as follows:

1. Use CG-PROPELLER to get a reference image $I(k_x,k_y)$ from $S^o_{b,c}(k_x,k_y)$.
2. Fourier transform $I(k_x,k_y)$ back to k-space $S^r(k_x,k_y)$, then use sensitivity map to get N coils, re-grid each coil back to M blades to get regenerated multi-coil k-space PROPELLER data $S^r_{b,c}(k_x,k_y)$.
3. Get the absolute difference of the regenerated and the original data as $\Delta S_{b,c}(k_x,k_y) = |S^o_{b,c}(k_x,k_y) - S^r_{b,c}(k_x,k_y)|$.
4. Make an average of $\Delta S_{b,c}(k_x,k_y)$ in the readout direction to get difference plot $\Delta S_{b,c}(k_y)$. Apply energy compensation in the phase-encoding direction.
5. Put all blade plots $\Delta S_{b,c}(k_y)$ in an array to form coil difference plot $\Delta S_c(k_y)$.
6. Let $\Delta S_i = \Delta S_c(k_y)$ at i^{th} line in one coil, we detect the corrupted lines if the difference value satisfying following conditions:

a) $\Delta S_i > S,\ S = \alpha \cdot \mathrm{mean}(\Delta S_i),\ 1.1 < \alpha < 1.5$;

b) $\Delta S_i - \Delta S_{i+1} > \beta$ & $\Delta S_i - \Delta S_{i-1} > \beta$, $0.01 \cdot \mathrm{mean}(\Delta S_i) < \beta < 0.05\mathrm{mean}(\Delta S_i)$;

Where α and β are the parameters to be adjusted in practice.

7. The lines detected are discarded in the original data set $S^o_{b,c}(k_x,k_y)$ to form the corrected data $S^c_{b,c}(k_x,k_y)$. Then the final image is produced using CG-PROPELLER from the non-uniformly sampled $S^c_{b,c}(k_x,k_y)$.

Note that this whole process can form a loop, using the corrected image as reference and repeat the process again. As CG-PROPELLER is time consuming, we only present one-loop results.

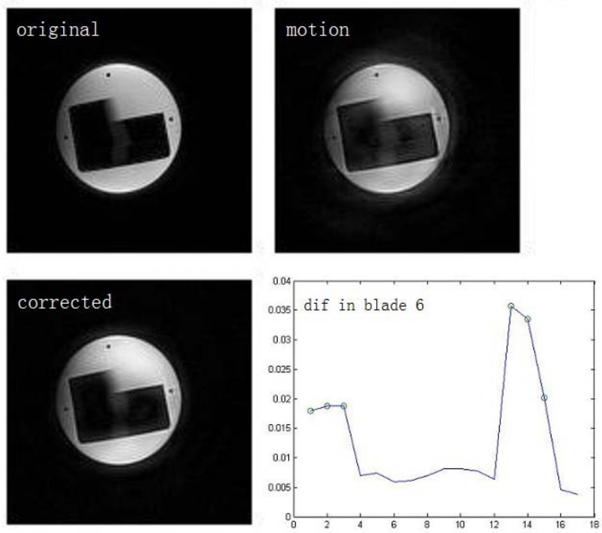

Fig.2 phantom results. In blade 6, lines 1 to 3, 13 to 15 are greatly larger than others as the result of introduced motion.

Results: The phantom results are illustrated in Fig.2. In an 8-coil phantom (128*17*30*8 as blade width*blade lines*blade number*coil number) experiment, data is corrupted with expanding motion in blades 4 to7,18 to 25 with lines 1 to 3, 13 to 15, and blades 8 to 15, 26 to 30 with lines 2 to 6, 11 to 16 in all 8 coils. As shown in Fig.2 (c), the expand motion artifacts are corrected substantially using the proposed method. The difference plot for blade 6 (Fig.2d) indicates the corrupt lines 1 to 3 and 13 to15 are detected.

Fig.3 shows an in-vivo experiment which was performed on a 3T Philips MRI scanner with a volunteer deliberately moving his head around. The acquisition parameters are: TR/TE=2000/105ms, TSE=34, shorts per blade=1, coil number=8, blade number=15, matrix size=256. We can see the proposed method enhanced the correction of motion, especially for the artifacts caused by through-plane motion.

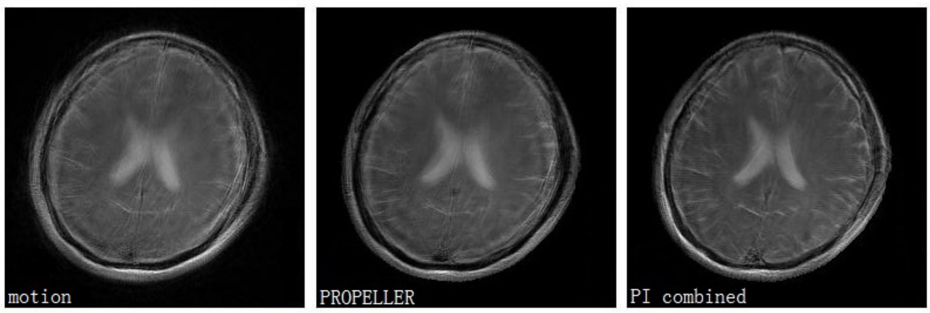

Fig.3 In-vivo results with a volunteer deliberately moving his head around. Traditional PROPELLER correction is compared with PI combined PROPELLER.

Discussion and Conclusion: When combined with PI, PROPELLER demonstrates enhanced non-rigid motion correction besides rigid motion correction. The method is post-acquisition and requires no adjustment on pulse sequence and hardware. No prior knowledge of the motion is required since the corrected data is obtained from the existing data. In this work, the optimization of the detection scheme requires further study. Other applications e.g. abdominal experiments are still undergoing.

References: [1]Pipe MRM 1999:42:963–969 [2]Bydder et.al MRM 2002:47:677–686 [3]Samsonov et.al MRM 2010:63:1104–1110