Evaluation of In-Plane Motion Correction in PROPELLER-MRI

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Introduction:

PROPELLER-MRI (Periodically Rotated Overlapping Parallel Lines with Enhanced Reconstruction) is based on multiple-shot fast spin-echo acquisitions and is characterized by significantly reduced sensitivity to B_0-related and motion-related artifacts [1]. In PROPELLER, several k-space lines are acquired in each TR, forming a blade that is then rotated around its center and acquisition is repeated to cover k-space. A central disc of k-space is acquired in each blade, that can be used as a 2D navigator to correct data between shots without requiring additional echoes [2]. In this work, the performance of the motion correction algorithm used in PROPELLER is investigated for various sampling patterns, in order to determine acquisition schemes that would maximize the correction of motion.

Methods:

Simulations of PROPELLER data acquisitions were performed. The simulated object was the Shepp-Logan phantom for which the value at any point in k-space is known analytically [3]. No noise was added to the data. If b, l stand for blades and lines per blade, then the k-space sampling patterns that were simulated were (S={b, l}): SB1={12,l6}, SB2={16,l6}, SB3={20,l6}, SB4={24,l6})**.** In this set of patterns, different numbers of blades with the same number of lines were distributed evenly through k-space**.** Sampling patterns SL1={12,16}, SL2=(12,24), SL2=(12,32), SL3=(12,40), SL5=(12,48), were created by increasing the number of lines while keeping the number of blades constant. Each line contained 128 samples. Random rotations within a range of ±5°, and translations within ±5 voxels were simulated in each blade, and for all sampling patterns. In-plane rotations and translations were estimated, and corrected using methods previously presented [2]. The absolute value of the error in rotation and translation that remained after motion correction was estimated for each blade. Then the total translation and total rotation errors were estimated for each sampling pattern by adding the errors from all blades in the pattern. The same process was repeated 300 times. The mean rotation and mean translation errors were calculated for each sampling pattern. In order to be able to make comparisons between schemes with different numbers of blades, all mean errors were multiplied by 12 and divided by the number of blades in the pattern. Finally, for SL3, the performance of the motion correction algorithm was tested for different amounts of rotation (0°,±1°,±3°,±5°,±7°,±9°) while keeping the range of translations at ±5 voxels. The same procedure was repeated for different amounts of translation (0,±1,±3,±5,±7,±9 pixels) while keeping the range of rotations at ±5°. The precision of the motion correction algorithm in estimating rotations and translations was 0.1° and 0.5 pixels respectively.

Results and Discussion:

Figure 1 shows translation and rotation mean errors for patterns with different numbers of lines or blades. Increasing the number of lines per blade resulted in less rotation error (Fig.1a). However, for more than 32 lines there was no further reduction in rotation error. Increasing the number of blades appeared to increase the mean rotation error (Fig.1b). This result is counterintuitive, but may be due to the metric used to assess the performance of the motion correction algorithm. Figures 1c,d show that the mean translation error does not depend significantly on either the number of blades or the number of lines per blade of the sampling pattern. These findings are of significant importance, since they suggest that after some specific number of lines or blades the result of the motion correction algorithm cannot be further improved. That limit depends on the imaged object (since for example a circular object with uniform intensity will have high mean rotation error independent of the number of lines per blade). Figure 2 shows translation and rotation mean errors as function of the degree of rotation and translation simulated. When keeping the degree of rotation constant and varying the degree of translation, the mean rotation error is significantly reduced only when no translation is applied (Fig.2a). For higher amounts of translation the rotation error is relatively unchanged. However, the mean translation error increases as the degree of simulated translation increases (Fig.2b). When keeping the amount of translation the same and varying the degree of simulated rotation, the mean rotation error increases continuously (Fig.2c), while the mean translation error remains relatively constant (Fig.2d). These results demonstrate that the degree of simulated translation does not significantly affect the rotation error, and the degree of simulated rotation does not significantly affect the translation error. Further research on actual phantoms are necessary to verify these findings.

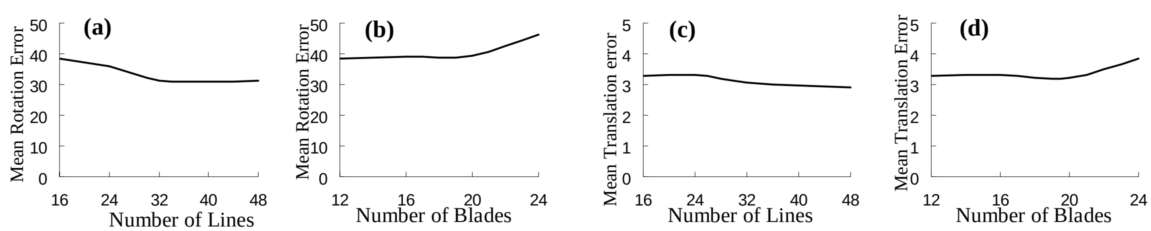

Figure 1: Plots of mean translation and mean rotation error as a function of the number of blades and lines per blade of the PROPELLER sampling pattern.

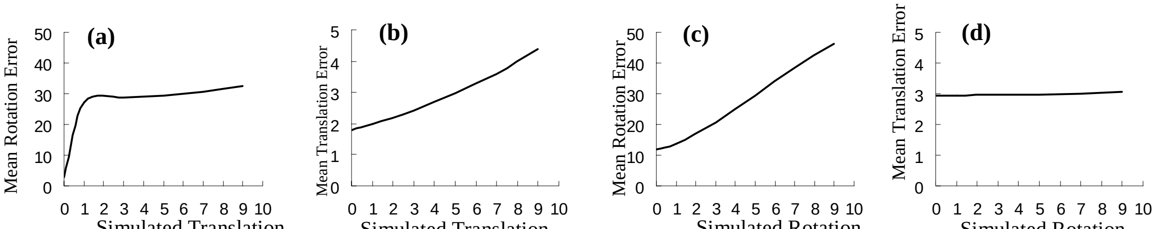

Figure 2: Plots of mean translation and mean rotation error as a function of the degree of translation and rotation, while keeping the degree of rotation (a,b) and the degree of translation (c,d) constant.

References:

1) Pipe JG, Farthing VG, Forbes KP. Magn. Reson. Med 47:42-52 (2002) 2) Pipe JG. ISMRM 2001;p.743 3) Shepp LA, Logan BF, IEEE Trans Nucl Sci NS-21:21 (1974).