Improved Motion Correction in PROPELLER by using Grouped Blades as Reference

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TARGET AUDIENCE: Researchers and clinicians interested in motion correction

PURPOSE: Periodically Rotated Overlapping ParallEL Lines with Enhanced Reconstruction (PROPELLER) is a data collection and reconstruction method for correcting rigid motion [1]. In PROPELLER, data are collected in continuously rotated blades, forming an oversampled circular area in the k-space center. Data in this area are used as reference for calculating rotation angle and translation shift of each blade, so. the accuracy and performance of PROPELLER depend on how reference data are generated. In current practice, there are two methods to generate the reference, single-blade reference method (SBR) [2] and combined-blade reference method (CBR) [1,3]. However, these two methods may fail in certain scenarios, for example, when the head to be imaged is oriented in two main directions (we call this bipolar motion). In this study, a new method called grouped–blade reference (GBR) is proposed for reference generation. Instead of using a single blade or all the blades, our method groups blades with the similar orientations together. This method can be regarded as a synthesis between SBR and CBR. Preliminary results show that GBR method needs less iteration to converge when implementing reconstruction in an iterative way, and is able to give results with higher quality compared to CBR and SBR.

METHODS: After PROPELLER data acquisition, all blades are firstly gridded onto Cartesian grids in k-space. Then they are classified into several groups based on their relative similarities. The similarity is measured by correlation coefficient between any two blades *Bi* and *Bj*, using the following formula:

$$r(i,j)=\frac{1}{\sqrt{\sum_{p\in R}|B_i(p)|^2}\cdot\sqrt{\sum_{p\in R}|B_j(p)|^2}}\begin{cases}\sum_{p\in R}|B_i(p)|\cdot|B_j(p)| & \text{for rotation}\\ \left|\sum_{p\in R}B_i(p)\cdot B_j^*(p)\right| & \text{for translation}\end{cases}\qquad i,\ j=1,2,\dots,\ N\ ,$$

where p refers to each pixel, R is the oversampled circular area with diameter equal to the width of each blade, $|B_i(p)|$ is the amplitude of k-space signal of i-th blade at location p. Blades with higher correlation, indicating that they are more similar with each other than with other blades, are supposed to fall in the same group. Based on this basic principle, a classification algorithm is developed to group blades. We choose the group with the most members (blades) and combine those blades as the reference for the following rotation and translation correction. The PROPELLER reconstruction is implemented in an iterative manner. At the beginning of each iteration, the reference is updated with corrected blades from previous iteration.

GBR method was tested with simulation and *in vivo* data. Computer simulations were performed on static phantom data to validate the proposed method. The phantom image was acquired by a TSE sequence on Philips 3T scanner (Philips Healthcare, Best, the Netherlands). Blade data were numerically sampled using discrete Fourier Transform according to PROPELLER sampling trajectories. 15 blades were used to cover the full k-space for a single slice, with 34 frequency-encoding lines in each blade. Bipolar motion was added to the static phantom image. Blades 1~7 were subject to random rotation within [+23°, +46°] and random translation within [-15.4, -10.2] pixels, and blades 8, 10~15 were subject to random rotation within [-40°, -17°] and random translation within [+10.2, +15.4] pixels. In this way, these blades are classified into 2 groups, each of which is located around one principal position. Therefore, blades are distributed in a bipolar manner. One blade (blade 9) was then corrupted after applying motion.

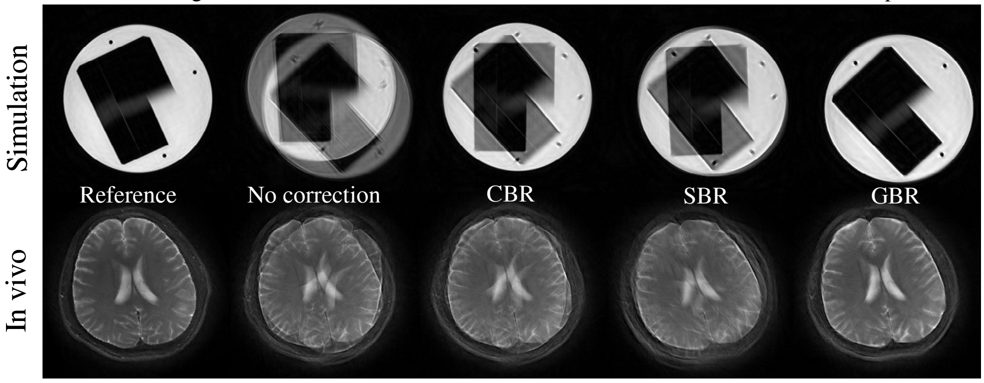

Fig. 1 Simulation and in vivo results from different reference generation methods. The motion to be corrected here has bipolar pattern. From left to right are reference images without motion, with motion, corrected with CBR, SBR and GBR. GBR has the most efficient correction effect for the specific motion here.

Healthy volunteers were recruited and provided informed written consent for *in vivo* studies. Brain data were acquired using a TSE based PROPELLER sequence with a 8-channel head coil. The sequence had a TR/TE of 3000/80 ms, 6-mm slice thickness and the resolution of 0.9×0.9mm^2. Each blade had 24 phase encoding lines and 20 blades were collected for a single slice. During the data acquisition, volunteers were instructed to perform bipolar motion.

RESULTS AND DISCUSSION: Fig. 1 shows computer simulation and *in vivo* results by iterative PROPELLER from different reference generation methods. For simulation data, the iteration numbers for CBR, SBR and GBR are 8, 8 and 2, respectively. For *in vivo* data, the iteration numbers of CBR, SBR and GBR are 5, 5 and 3 respectively. GBR requires less iteration to get more accurate correction than the other two methods, thus providing the most efficient correction performance. As the iteration goes, GBR manages to gather more similar blades, making the reference more consistent and concentrated. This accelerates the converging process of iterative PROPELLER. During the reference selection for PROPELLER reconstruction from corrupted or unevenly distributed blades, similar ones are preferable while dissimilar ones should be avoided from interfering with correction process. By collecting similar blades in a group, one can stay out of the problem about unfortunate choice of single corrupted blade. One can also avoid including dissimilar data into the reference, which may lead to slow convergence. As a result, the GBR inherits the merits of SBR and CBR and thus provides accurate correction with less motion-induced artifacts.

CONCLUSION: GBR for reference generation in PROPELLER reconstruction has been developed and validated in numerical simulation and *in vivo* experiments. The proposed method permits rigid motion correction with high accuracy and low computational cost. This method could be particularly useful for mitigating problems caused by patient motion.

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