

Application of k-space energy spectrum analysis to artifact correction in PROPELLER EPI

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Introduction

The imaging pulse sequence that integrates PROPELLER (i.e., *Periodically Rotating Overlapping Parallel Lines with Enhanced Reconstruction*: Fig. 1) and EPI (i.e., echo-planar imaging) has proven highly valuable for studies that require high throughput and high tolerance to subject motion [1,2]. However, the PROPELLER-EPI quality is usually degraded by geometric distortions resulting from background susceptibility field gradients [3]. Although the distortion can potentially be corrected through B0 mapping, it is not easy to use a conventional B0 mapping procedure to quantify the field inhomogeneity patterns, which may change from blade to blade due to subject motion. The goal of this study is to characterize the B0 field inhomogeneity patterns directly from each blade of the PROPELLER-EPI data using the k-space energy spectrum analysis (KESA) [3], enabling effective distortion correction even in the presence of intra-scan motion. Our novel approach that integrates the PROPELLER-EPI acquisition and KESA-based artifact reduction makes it possible to reliably generate high-quality and high-throughput MRI data.

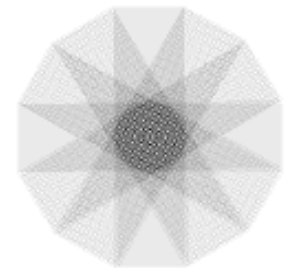


Fig. 1. PROPELLER sampling

Methods

The fundamentals of PROPELLER EPI for motion correction are based on that a rotation by angle θ has the same rotation angle θ in its Fourier transform and that a translation in image space leads to a linear phase shift in its Fourier transform. Since every sampling blade overlaps within a small circle around the central k-space, these data can be used to calculate and correct motion artifacts (rotation and translation). However, when off-resonance factors (e.g. B0 field inhomogeneity) appear during the PROPELLER-EPI sampling, different blades will have different field inhomogeneity components along frequency and phase encoding directions, resulting in inconsistent distortions. What's worse, the blades will be blurred severely when subject motion occurs during the PROPELLER-EPI scan. To eliminate both motion and distortion artifacts, we propose that instead of multi-TE B0 field mapping, KESA can be used to map B0 field inhomogeneity directly from each blade of PROPELLER-EPI data. Specifically, using an iterative partial Fourier reconstruction, KESA can quantify the k-space energy peak displacement, which can be converted to the corresponding B0 map for each blade [3]. The undistorted image (Fig. 2 (a)) and its corresponding B0 map (Fig. 2 (b)) were used to produce EPI data corresponding to different levels of rotation translation through a mathematical simulation. We then apply PROPELLER to correct for motion artifacts and then KESA to correct for distortion for every sampling blade. Finally, a gridding algorithm is used to reconstruct the final image.

Results and Discussion

Fig. 2 shows the reconstruction procedure using our proposed method. Four distorted images corresponding to different sampling blades are shown in (c), and the quality of PROPELLER-combined image shown in (e) based on these blades is degraded severely. The images in (c) can be moved to their original positions after motion correction with PROPELLER and transformed to their undistorted form using B0 maps derived from every blade calculated with KESA, as is shown in (d). The final reconstructed image in (f) is much better matched with the input shown in (a). The results demonstrate that the KESA can be used to eliminate distortion artifacts in PROPELLER-EPI MR images. Future works may involve more accurate motion estimation and B0 mapping calculation to improve the robustness and efficiency of this method.

References

[1] Pipe, J.G., MRM 42:963, 1999. [2] Wang, F.N., et al., MRM 54:1232, 2005. [3] Chen, N.K., et al., Neuroimage 31:609, 2006.

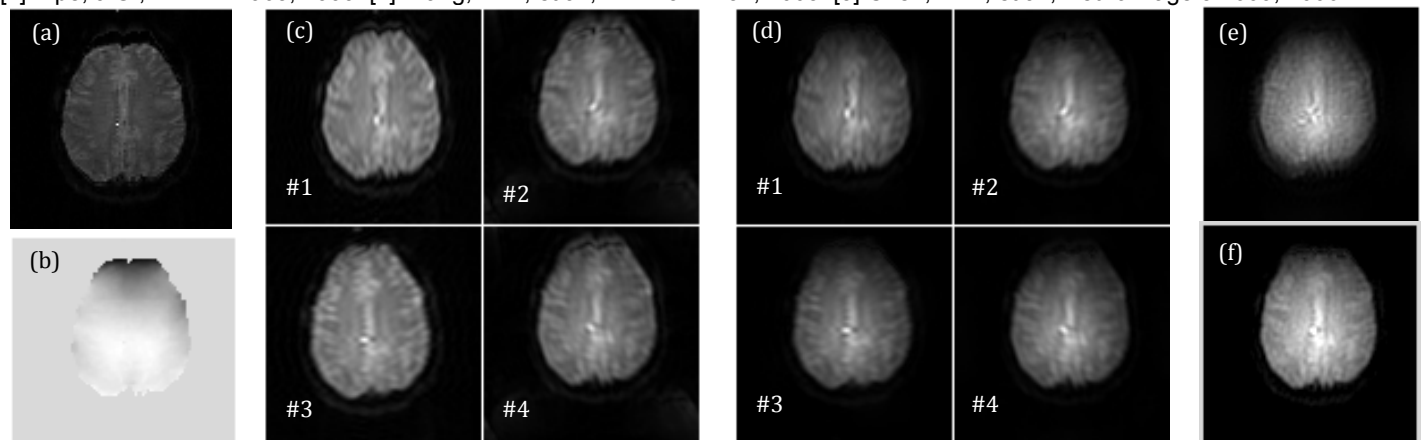


Fig. 2. Reconstruction procedure. (a) Original image and (b) B0 map. (c) Blades with motion and distortion artifacts. (d) Blades after motion and distortion correction. Reconstruction (e) before and (f) after KESA-based correction.

