Contrast Optimization by Data Weighting in Propeller Imaging

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Introduction

Propeller imaging has proven to be an acquisition and reconstruction method that increases tolerance to motion in a variety of applications [1]. It relies on a hybrid Cartesian-radial k-space sampling to correct mainly rigid in-plane motion by cross-correlating the data from different sub-acquisitions, so-called blades. The resulting oversampling of the central k-space area additionally permits a reduction of artifacts arising from other motion by prioritizing the data according to correlation measures [1,2]. If Propeller imaging is to replace Cartesian imaging in a larger variety of applications, it has to provide the same range of contrasts. In combination with fast spin echo sequences, primarily its higher susceptibility to transverse relaxation turns out to be problematic, since the stronger effect of signal decay on the central k-space area complicates the suppression of T_2 weighting. Compensating for it by a reduction of the echo train length would compromise both the scan efficiency and the motion correction. This work, therefore, explores an alternative for proton density weighted imaging based on data weighting.

Methods

To reduce the influence of data from later echoes, we adapt the sampling density compensation [3]. We initially assign a relative weight of

$$w_n = e^{-\lambda \Delta TE\, n}$$

to each k-space line, where λ denotes a decay constant, ΔTE the echo spacing, and n the echo number. We then combine these weights with the sampling density compensation in an iterative procedure [4]. The effect of λ on the resulting weights and signal distributions in k-space is illustrated in Figs. 1 and 2. Higher values of λ lead primarily to an improved homogeneity of signal strength in the central k-space area, where a choice between samples from different echoes exists. At the same time, the non-uniformity of the weights increases, entailing a loss in SNR quantified in Fig. 3. We evaluated the potential and limits of this approach in simulations and in volunteer experiments on a 1.5 T Philips Achieva scanner.

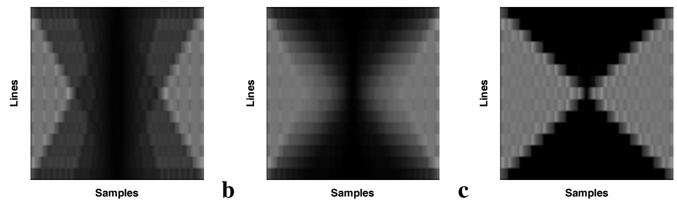

*Fig. 1. Weights applied to the data in k-space for a λ of (**a**) 0.0/ΔTE, (**b**) 0.2/ΔTE, and (**c**) 2.0/ΔTE.*

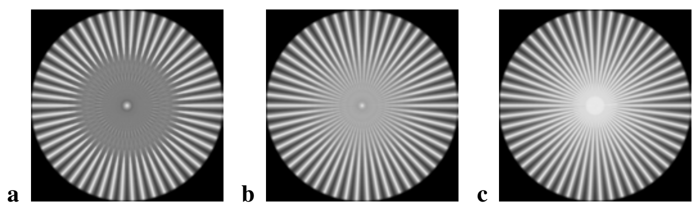

*Fig. 2. Signal distributions in k-space for a decaying point source, using a low-high acquisition order for each blade and a λ of (**a**) 0.0/ΔTE, (**b**) 0.2/ΔTE, and (**c**) 2.0/ΔTE.*

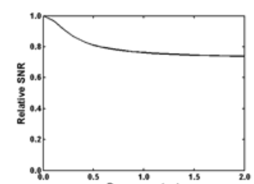

Fig. 3. SNR penalty for the contrast optimization as function of λ in units of 1.0/ΔTE.

Results

Fig. 4 summarizes results for a simulated acquisition with 17 blades, 15 lines, 15 echoes, and ΔTE=10 ms. The relaxation rates were 0.0 ms^{-1}, 0.01 ms^{-1}, and 0.02 ms^{-1}. Without contrast manipulation, the original differences in signal strength are mostly lost. Using higher values of λ permits to recover them, although artifacts due to remaining inconsistencies in the peripheral k-space area appear more pronounced.

Fig. 5 confirms these observations in experiments. The data were obtained with 45 blades, 18 lines, 9 echoes, and ΔTE=8 ms. The differences in signal notably between CSF and brain tissue increase with λ, but artifact and noise levels rise as well.

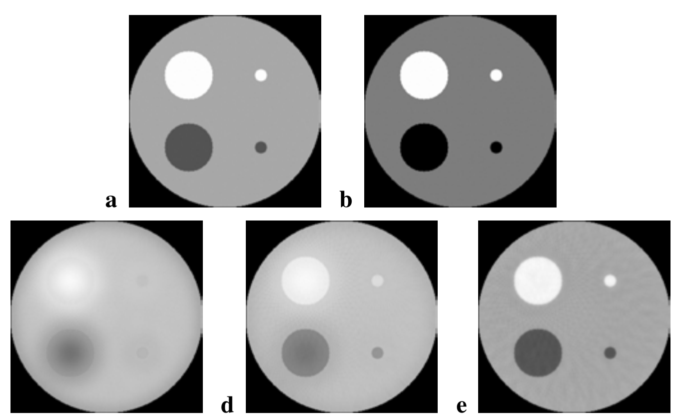

*Fig. 4. Simulation results. (**a**) Phantom. (**b**) R_2 map. (**c**)-(**e**) Images reconstructed with a λ of (c) 0.0/ΔTE, (d) 0.2/ΔTE, and (e) 2.0/ΔTE.*

Conclusions

Prioritizing the data according to acquisition times allows to optimize contrast in Propeller imaging. Without compromising reconstruction fidelity, this approach is restricted to the central k-space area. Thus, artifacts remain and set, together with the inherent sacrifices in SNR, a practicable limit on the ability to manipulate contrast by data weighting.

References

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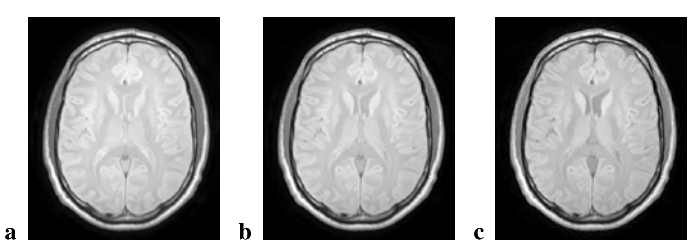

*Fig. 5. Experimental results. (**a**)-(**c**) Images reconstructed with a λ of (a) 0.0/ΔTE, (b) 0.2/ΔTE, and (c) 0.5/ΔTE.*