Model-Based Phase-Difference Reconstruction for Accelerated Phase-Based T_2 Mapping

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Introduction

Quantitative T_2 mapping is of great interest in clinical MRI. While conventional T_2 mapping employs multi-echo spin-echo acquisition and utilizes magnitude images at various TEs for T_2 estimation, a recent T_2 mapping technique based on the phase difference of two distinct RF-spoiled steady- state gradient-echo acquisitions (with two different RF phases) has been proposed [1]. The phase-based method reconstructs two sets of complex images individually and is followed by phase difference calculation. In this work, instead of reconstructing two individual images for phase difference calculation, we propose to reconstruct the phase-difference maps directly from k-space by formulating image reconstruction as a nonlinear inverse problem. In such a way, the number of unknowns is reduced from two complex images to one complex and one real image. Moreover, sparsity constraints can be directly applied to the phase-difference maps, allowing for further acceleration.

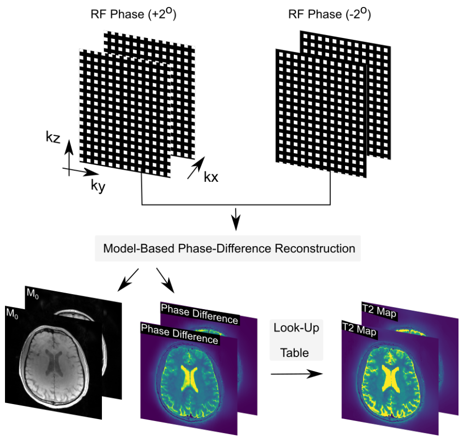

Figure 1: Schematic diagram of the overall data acquisition and image reconstruction strategy for phase-based T_2 mapping with model based reconstruction.

Methods

MOdel-BAsed (MOBA) Phase-Difference Reconstruction

Phase-based T_2 mapping involves the acquisition of two GRE volumes with a small and opposite RF phase offset. These volumes can be described as

$$\text{Signal}_1 = M_0 \cdot e^{i\phi + i\delta\theta}$$

and

$$\text{Signal}_2 = M_0 \cdot e^{i\phi - i\delta\theta}$$

We define $B = M_0 \cdot e^{i\phi + i\delta\theta}$, thus making $\text{Signal}_2 = Be^{-i2\delta\theta}$. As such, we need to estimate the complex-valued B and real-valued $\delta\theta$ during the reconstruction. When combined with the coil sensitivities C, Fourier encoding matrix $\mathcal{F}$ and the subsampling mask P, we have:

$$F : x = \left(B, \delta\theta\right)^T \mapsto P\mathcal{F}C \cdot B \cdot e^{i \cdot 2 \cdot \delta\theta}.$$

To estimate $(B, \delta\theta)^T$, we adopt the model-based reconstruction in BART [2-4] to estimate B and $\delta\theta$ jointly from the two acquired GRE volumes and employ GPU acceleration. Fig1. demonstrates the data acquisition and image reconstruction strategy.

Data acquisition

All data were acquired on a 3T Prisma system with 32 channel reception. The pulse sequence was modified from a 3D-GRE product sequence so that RF phase increments and gradient spoiling moments could be adjusted [5]. All experiments used RF phase increments of +2 and -2 degrees. B1 corrections were performed for the flip angles using separately acquired B1 maps. Phantom data were obtained using a uniform fBIRN phantom at 1 mm iso. resolution with TE/TR = 2.62 / 10 ms and flip angle = 10 degrees, and FOV=192 x 192 x 168 mm^3. In vivo data: a healthy volunteer was scanned at 1 mm iso. resolution and fully sampled data were obtained, which was retrospectively undersampled. The scan parameters include TE/TR = 2.62 / 10 ms and flip angle = 15 degrees, and FOV = 214 x 214 x 168 mm^3.

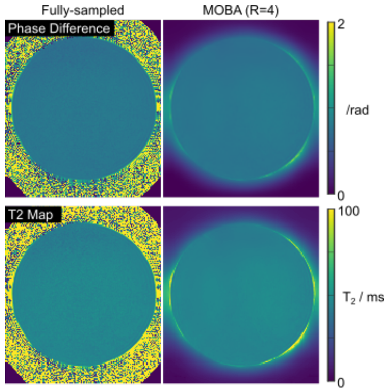

Figure 2: Phase difference and T_2 maps from the uniform fBRIN phantom. Quantitative T_2 values are 46±1 ms vs 47±1 ms for the fully-sampled and MOBA reconstruction at R=4, respectively.

Results & Discussion

Fig2. depicts the results from the fBIRN phantom experiment. As anticipated, both phase difference and T_2 map reconstructions are highly uniform in this phantom. Fully-sampled and R=4-fold accelerated MOBA T_2 maps are highly similar, with mean values of 46 and 47 ms respectively. Fig3. compares M_0 and T_2 estimates obtained from the proposed MOBA and SENSE reconstructions at R=4 with the fully-sampled data. The T_2 maps were obtained using a pre-computed dictionary while incorporating B1 corrections. MOBA is seen to closely match the fully-sampled reference, with improvements over SENSE in image quality, especially in the M_0 map.

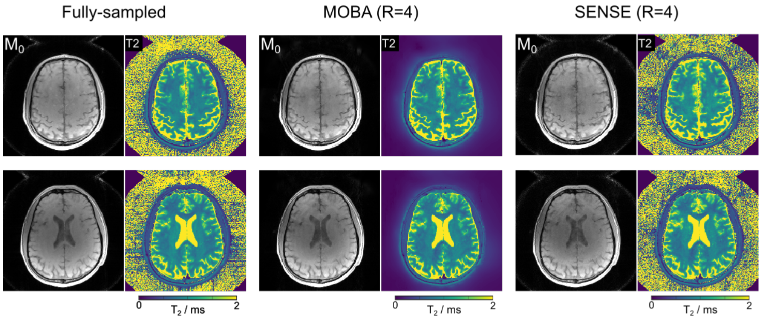

Figure 3: Two representative slices from the in vivo experiment are shown. Proposed MOBA at R=4 yielded high quality M_0 and T_2 estimates, with improvements over the standard SENSE reconstruction.

Discussion and Conclusion

We proposed a model-based reconstruction, MOBA to exploit redundancies in phase-based T_2 mapping acquisitions. Since the acquired two GRE volumes differ only in their phase, we have capitalized on this to reduce the number of unknowns and jointly reconstructed a phase difference image directly out of the undersampled k-space data. MOBA flexibly admits additional regularization, is integrated with BART and can exploit GPU acceleration. It provided high quality T_2 estimates from a moderate R=4-fold acceleration. Future directions include higher acceleration factors, deploying this acquisition at ultra high fields [5] and wave encoded reconstructions [6] to push the efficiency and resolution.

References

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