Nonlinear Inverse Reconstruction for T2 Mapping from Highly Undersampled Cartesian Spin-Echo MRI

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Introduction:

Quantitative evaluations of the T2 relaxation time are of high importance for diagnostic MRI. Standard T2 mapping procedures rely on the time-demanding acquisition of several fully-sampled k-space datasets at multiple echo times. Recently, a new method has been proposed which employs a nonlinear inversion of the underlying signal equation to allow for reconstructions of spin-density and T2 maps from highly undersampled data [1]. The original implementation employed radial k-space trajectories as well as a heuristically chosen scaling factor for different anatomical regions. In this work, we further developed this method towards Cartesian acquisition schemes as they are most widespread in clinical applications today. The necessity of manual adjustments is removed by an automatic scaling routine.

Materials and Methods

Spin-echo MRI experiments (phantoms, human brain) were conducted at 2.9 T (Siemens Tim Trio) using both a single-element and 32-element head coil as well as 16 echoes with echo spacing ΔTE = 12.2 ms and TR = 3000 ms (5 sections, 1.0 × 1.0 × 4.0 mm^3 resolution, 192 × 160 matrix, acquisition time without undersampling = 8 min).

Reconstructions of spin-density and T2 maps were performed using an adapted version of the algorithm [1]. The performance of different undersampling schemes with variable acceleration factors (**Fig. 1 left**) was compared by selecting respective k-space lines from the fully sampled data.

To avoid bad conditioning of the reconstruction, the partial derivatives of the cost function were balanced with respect to the spin-density and T2 map by additional scaling coefficients. These scaling values were automatically deduced from low-resolution parameter maps created from the samples of the k-space center available at different echo times.

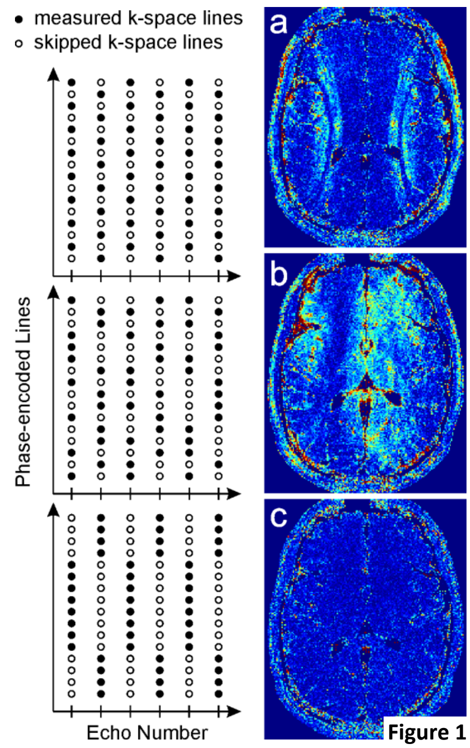

Figure 1

Results

Reconstructions from undersampled numerical phantom data revealed residual aliasing artifacts in regions violating the mono-exponential model assumption (data not shown). The impact of these artifacts can be reduced with the use of a suitable sampling strategy such as a blocked sampling pattern (**Fig. 1c**), see examples from a human brain study (**Fig. 1 right**). These were obtained for T2 acquisitions using a single-element coil and represent the difference between reconstructions from fully sampled data and two-fold undersampled data for a uniformly interleaved pattern (**Fig. 1a**), an interleaved random pattern (**Fig. 1b**) and the recommended blocked pattern (**Fig. 1 c**). Reconstructions of spin-density and T2 maps from acquisitions with a 32-element coil are shown in **Fig. 2** for a fully sampled reference (1) as well as for acceleration factors of 5 and 10 (again using the blocked pattern).

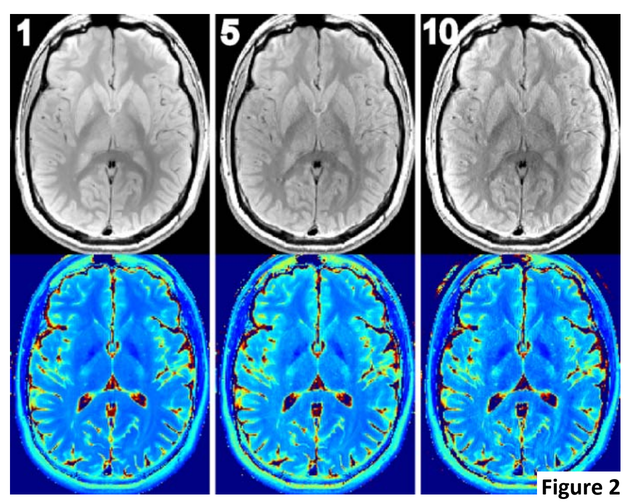

Figure 2

Conclusion:

Depending on the available SNR, the proposed method allows for very high undersampling factors by exploiting data redundancy in parameter space. Aliasing artifacts at image discontinuities may effectively be suppressed by a blocked undersampling scheme as shown in **Fig. 1c**. The new scaling technique ensures robust reconstructions for data from different anatomical regions and MRI systems. The method does not depend on parallel imaging and even works in settings where only a single or very few coils are available. This feature is of particular interest for animal MRI studies, where coil arrays with more than 4 elements are far less common than in state-of-the-art human MRI systems.

References:

[1] Block KT et al, IEEE Trans Med Imaging 2009;28:1759-1769.