Order of Magnitude Speed-up in 2pt Dixon Water/Fat Separation Processing

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Purpose: Efficient and robust water and fat separation algorithms for MRI image data are of great clinical interest [1]. Beyond the ability to quantify fat content, it has also been used to provide fat-suppression for dynamic contrast enhanced liver imaging [2]. Conventional 2pt-Dixon methods typically require image acquisition at the so-called in-phase and opposed-phase echo times, requiring a TE difference (ΔTE) of 2.2ms at 1.5T [3]. For faster data acquisition, flexibility in ΔTE is desired and the corresponding algorithms have been developed [4, 5, 6]. These algorithms all rely on the assumption that the inhomogeneity field is spatially smooth or lies close to the initial guess. This field can be calculated using region growing methods, global optimization or iterative smoothing methods. Once the field is calculated, the water and fat components can be easily derived from the acquired image data. Here we propose a new approach for inhomogeneity field calculation by adopting the methods used in susceptibility mapping for the removal of the background field [7, 8]. This results in a significant speedup of the fat/water separation step. We demonstrate water/fat separation for liver imaging acquired using a dual echo spiral acquisition with TE1/TE2=0.65ms/1.22ms at 1.5T.

Theory: In 2pt-Dixon method, the signal equations are given by

$$W' + F'e^{i\theta_1} = S_1$$
$$(W' + F'e^{i\theta_2})e^{-i\delta} = S_2$$

where W' and F' are the complex water and fat signals, S_i are the measured signals, $\theta_i = \Delta\omega \times TE_i$ is the water/fat phase difference due to the chemical shift. For 1.5T main field, $\Delta\omega = 2\pi \times 230Hz$.

The error phase δ is due to both the background field inhomogeneity and the sample susceptibility inhomogeneity. For typical samples, the former dominates, and we can calculate the error phase δ using two background field removal algorithms: the projection onto dipole fields (PDF) algorithm [7] and the sophisticated harmonic artifact reduction for phase data (SHARP) method [8]. When δ is known, the water and fat signals can be readily calculated from:

$$\begin{pmatrix} W' \\ F' \end{pmatrix} = \frac{1}{e^{i\theta_2} - e^{i\theta_1}} \begin{pmatrix} e^{i\theta_2} & -e^{i\theta_1} \\ -1 & 1 \end{pmatrix} \begin{pmatrix} S_1 \\ S_2 e^{i\delta} \end{pmatrix}$$

and the corresponding water/fat magnitude images are $W = |W'|$ and $F = |F'|$ [5].

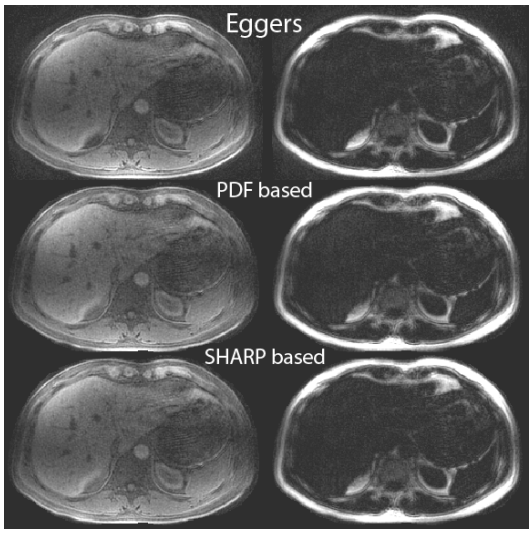

Figure 1. Water and fat map calculated from (top row) the algorithm in Ref. [5]; (middle row) the proposed algorithm with background field derived using PDF method; (bottom row) the proposed method with background field derived using SHARP method.

Materials and Methods: Liver images were acquired in a healthy volunteer on a 1.5 T scanner (GE Healthcare). Imaging parameters were: 48 leaves, 256x256x28 acquisition matrix, 11s scan time per echo time, ±62.5kHz bandwidth, flip angle 15° and TE1/TE2=0.65ms/1.22ms. All algorithms were implemented in Matlab and total processing time was recorded.

Results: Comparison of the water/fat images derived from the iterative solver developed by Eggers et al [5] and the proposed methods is shown in Figure 1. Image qualities between the three methods were judged to be similar by an experienced radiologist. The corresponding computation costs were 36.15s (Eggers), 10.08s (PDF based) and 4.26s (SHARP based).

Discussion and conclusion: The preliminary results in this study show that significant speed-ups can be achieved in the fat-water separation step by a separate estimation of the inhomogeneity field. The same inhomogeneity field can subsequently be used to perform off-resonance correction on both the water and fat image. Combined with the flexibility in the choice of the echo time difference, the dual echo spiral acquisition is suitable for dynamic contrast enhanced liver MRI without a significant increase in either acquisition or reconstruction time.

Reference: [1] Ma 2008. JMRI (28) 543-558; [2]Saranathan et al, JMRI 35(6) 1484 [3] Ma 2004. MRM (52) 415-419; [4] Xiang 06. MRM (56) 572-584; [5] Eggers et al. 2011. MRM (65) 96-107; [6] Berglund et al. 2011. MRM (65) 994-1004; [7] Liu et al. 2011. NMR in BioMed (24) 1129-1136; [8] Schweser et al. 2011. NeuroImage (54) 2789-2807.