

Imaging Water, Fat, and Silicone with Regional Iterative Phasor Extraction (RIPE)

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Introduction

Recently, an effective phase correction algorithm of Regional Iterative Phasor Extraction (RIPE) has been described for two-point water-fat imaging with partially-opposed-phase (POP) acquisition [1]. Since RIPE is able to address the key issue of phase correction in a straightforward manner without phase unwrapping, it is natural to use RIPE in other applications of simple spectroscopic imaging. In this work, RIPE is applied to obtain separate images of water, fat, and silicone associated with breast implant [2,3].

Methods

Theory For a system with three chemical components of water, fat, and silicone, the general signal equation [2] for a complex MR image can be written as Eqn.(1) where W , F , and C are non-negative real variables representing the amount of water, fat, and silicone in each voxel; A_1 and A_2 are

$$I_{n+1} = (W + FA_1^n + CA_2^n)P_0P_1^n \quad (1)$$

known phasors, in the form of $\exp(i\delta\omega\Delta t)$, describing chemical shift effect of fat and silicone relative to water, respectively; P_0 is a static error phasor available from an in-phase image; P_1 is an incremental error phasor to be found and corrected; n is an integer index representing the time increments of the data acquisition. For three images acquired with $n = 0, 1, 2$, and after removing the static error phasor P_0 [1], we have Eqns. (2-4). Although there are three chemical components in the image, each voxel is observed to contain

$$J_1 = W + F + C \quad (2)$$

$$J_2 = (W + FA_1 + CA_2)P_1 \quad (3)$$

$$J_3 = (W + FA_1^2 + CA_2^2)P_1^2 \quad (4)$$

only up to two components. This is true for most pixels in the image. For example, regions of pure water and silicone have only one component, and regions with lipids may have two components. With this consideration, a "Big" and a "Small" component can be readily obtained for each pixel by combining

$$P_a = J_2 / (B + SA_1) \quad (5)$$

$$P_b = J_2 / (B + SA_2) \quad (6)$$

$$P_c = J_2 / (S + BA_1) \quad (7)$$

$$P_d = J_2 / (S + BA_2) \quad (8)$$

any two of the three equations given by (2-4), in a similar manner as that in Ref.[1]. The final (B, S) solution pair is taken as the average of the three combinations for improved SNR. By substituting the available (B, S) solution pair into Eqn.(3), four possible error phasor candidates for P_1 can be formed as those in Eqns.(5-8). The true error phasor P_1 is locally selected as the most popular phasor candidate among neighboring pixels, considering the smoothness of phase error. Similar to Ref.[1], this is achieved by RIPE to extract a final smoothly varying phasor field P_{stable} from the 4 possible error phasors, representing the sought error phasor P_1 . P_{stable} is moderately smoothed for noise reduction [1] and removed from Eqns.(3) and (4), resulting in real valued least-squares solutions of (W, F, C) from Eqns.(2-4) as water, fat, and silicone images.

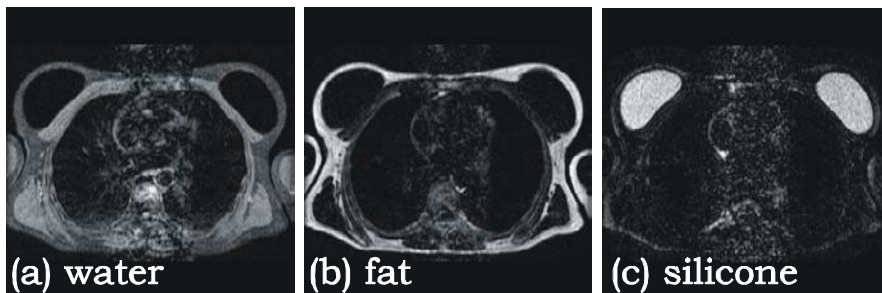
Experiments Axial multi-slice chest scans on subjects with breast implant were performed. Complex images were obtained by three interleaved spin-echo acquisitions with a sampling scheme of $(0^\circ, 90^\circ, 180^\circ)$ between water and fat (a factor of 1.34 larger between water and silicone [2]). The field strength was 0.5T that is more challenging than 1.5T or higher due to less chemical spectrum separation and lower SNR.

Results

Figures (a), (b), and (c) are images of water, fat, and silicone respectively, from a representative slice in a 15-slice scan. The qualities of these images are reasonable, with all three components successfully separated and identified. Motion artifacts did not cause failure of the algorithm, suggesting its robustness. The noise levels in the final images were also reduced as compared to the original complex images, as expected for multi-point Dixon imaging.

Discussion

Regional Iterative Phasor Extraction (RIPE) is effective for phase correction in imaging water, fat, and silicone. Compared with earlier approaches [2,3], the new algorithm is more straightforward without using phase unwrapping, requires less assumption about the chemical spectrum such as a 2 to 1 ratio for the two chemical shifts [3], and is faster.



References

- [1] QS Xiang, MRM, 56:572-584 (2006)
- [2] L An *et al*, MRM, 46: 126-130 (2001)
- [3] E Schneider *et al*, Radiology, 187: 89-93 (1993)