A hybrid homodyne algorithm for reconstructing partially acquired two-point Dixon data

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Background

The application of Dixon techniques for the separation of fat and water [1] has been hindered by the long scan time required for the acquisition of multiple images. Partial-Fourier acquisition and homodyne reconstruction have been effective in reducing scan time in many applications [2]; however, while images acquired in Dixon techniques are complex, homodyne reconstruction assumes that the object is real. Therefore, the two image reconstruction methods have generally been considered incompatible. In this work, we demonstrate that in a two-point Dixon technique where only fat and water in-phase and 180° out-of-phase images are acquired, Dixon and homodyne reconstruction can be combined to permit reduction of the scan time. Although a similar idea was previously used in combination with a partial-echo three-point Dixon acquisition [3], that approach required a third image with fat and water 90° out-of-phase, which precludes the use of homodyne reconstruction.

Methods

Assuming that W and F are the water and fat signals, respectively, and ϕ_0 and ϕ are the two phase error terms, the in-phase and 180° out-of-phase images from a complete data set can be represented as $S_{IP} = (W+F)e^{i\phi_0}$ and $S_{OP} = (W-F)e^{i(\phi_0+\phi)}$, respectively. According to Ref. 2, the in-phase and out-of-phase images reconstructed from asymmetrically acquired data (after zero-filling and accounting for the data asymmetry with a step filter) can be written as $S_{IP,ZF} \approx \left((W+F)+(W_H+F_H)*\frac{1}{i\pi x}\right)e^{i\phi_0}$ and $S_{OP,ZF} \approx \left((W-F)+(W_H-F_H)*\frac{1}{i\pi x}\right)e^{i(\phi_0+\phi)}$, where the subscript H denotes a high-pass filtered image and x represents the coordinate along the direction of data asymmetry. The reconstruction algorithm we propose to determine W and F is diagrammed in Fig. 1. Following data acquisition, two low-resolution images are reconstructed using the symmetric central portions of the in-phase and out-of-phase data. Then, ϕ_0 is determined as the phase of the low-resolution in-phase image and ϕ is determined from the low-resolution out-of-phase image using a previously described region-growing algorithm for phase correction of two-point Dixon data [4]. Afterwards, ϕ_0 and ϕ are used to demodulate $S_{IP,ZF}$ and $S_{OP,ZF}$. The two demodulated in-phase and out-of-phase images are finally combined to generate fat-only and water-only images.

The proposed algorithm was implemented in Matlab (Mathworks, Natick, MA). To evaluate its performance, we modified a conventional spin-echo pulse sequence to acquire two-point Dixon data. We imaged a water/fat phantom, as well as the knee of a volunteer. Both phantom and *in vivo* data were acquired on a GE Signa 1.5T whole-body scanner (GE Healthcare, Waukesha, WI) with a quadrature head coil. For the phantom experiment, a single axial slice with a full acquisition matrix of 512x512 was acquired in 5:12 minutes with the following parameters: TR/TE= 300/21ms, FOV= 20 cm, BW= ±15.63 kHz, frequency= L/R. In addition, a second set of data with a partial acquisition matrix of 512x272 (corresponding to 16 overscan lines) and scan parameters that were otherwise the same was collected in 2:55 minutes. For the *in vivo* experiment, a sagittal slice with a full acquisition matrix of 256x256 was acquired in 5:24 minutes with the following scan parameters: TR/TE= 600/14ms, FOV=24cm, BW=±15.63 kHz, frequency = S/I. A second set of data with a partial acquisition matrix of 256x144 (again corresponding to 16 overscan lines) was acquired in 3:09 minutes with an otherwise identical protocol.

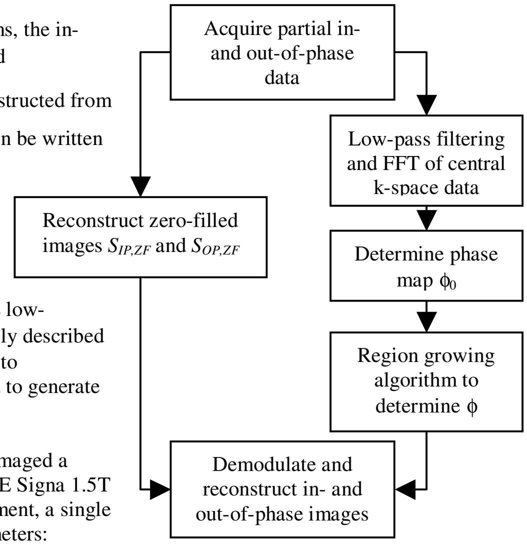

Fig. 1: Flow chart of the hybrid Dixon and homodyne reconstruction algorithm

Results

Fig. 2a) and 2b) show the water-only images of the phantom reconstructed from the data with the full and partial acquisition matrix, respectively. Comparison of the two images shows no noticeable difference in image quality. The same findings are also borne out in the *in vivo* images in Fig. 3. Fig. 4 plots the average profiles of the middle 20 lines that run perpendicular to the water/fat interface from the images in Fig. 2a) and Fig. 2b). Comparison of the two edge response functions indicates no loss of sharpness in the homodyne-reconstructed image relative to the image reconstructed from a complete data set.

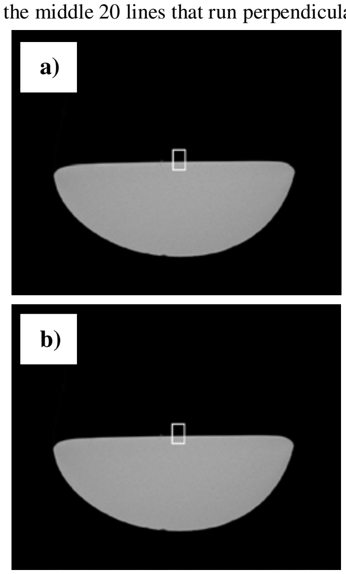

Fig. 2: Water-only images from the full (top) and partial (bottom) acquisitions show no difference in resolution, although the partial acquisition required only 53% of the full acquisition time.

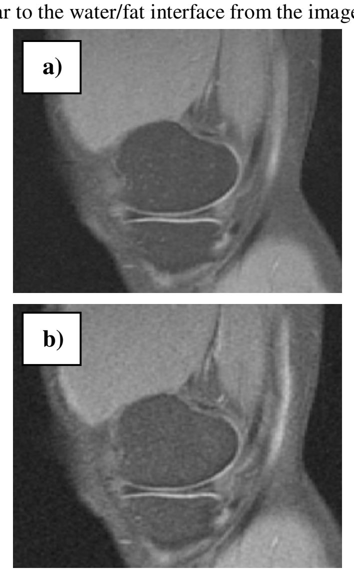

Fig.3: Water images from the full (top) and partial acquisitions (bottom) of a knee. The homodyne image, which was acquired in 56% of the time as for the full image, shows no noticeable resolution loss.

Discussion and Conclusions

Besides Dixon data with asymmetric echoes [3], combination of homodyne and Dixon reconstruction has also been reported recently in an iterative scheme for three point Dixon data [5]. In comparison to these previous approaches, our current algorithm requires only two-point Dixon acquisition and is thus intrinsically more time efficient. Phantom and *in vivo* results demonstrate that high-resolution water-only images can be obtained from partially acquired data, effectively eliminating the scan time penalty for the two-point acquisition with a full matrix.

References

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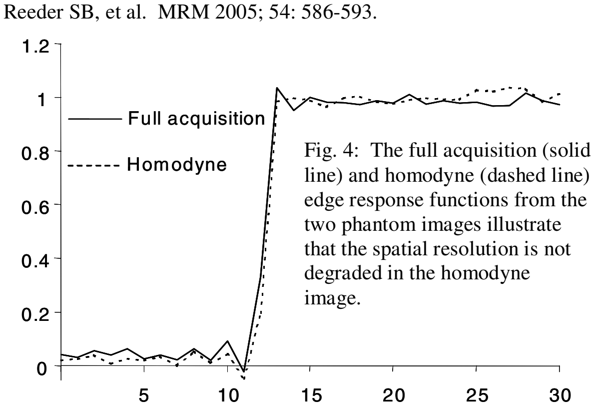

Fig. 4: The full acquisition (solid line) and homodyne (dashed line) edge response functions from the two phantom images illustrate that the spatial resolution is not degraded in the homodyne image.