# Water-Fat Identification for Analytical Multipoint Dixon's Method

Dinghui Wang[1] and James G. Pipe[1]
[1]Neuroimaging Research, Barrow Neurological Institute, Phoenix, AZ, United States

## Introduction

We recently presented an analytical method for multipoint water-fat imaging with flexible echo increments [1]. A critical step of this method is to resolve the static magnetic inhomogeneity (field map), water and fat from two sets of possible solutions. In this work, we propose a 3D post-processing algorithm based on regional iteration and region growing to reliably identify the field map, water and fat. The feasibility of the method is demonstrated with multi-channel spiral imaging.

## Theory

The signal model of the image at echo time $t_n$ is $S_n = (W + Fe^{i(2\pi\Delta f t_n+\phi)})e^{i(2\pi\Delta B_0 t_n+\theta)}$ $(n = 1, 2, 3 \ldots N)$. Real unknowns $W$, $F$ and $\Delta B_0$ are water, fat, and the field map, respectively. $\Delta f$ is the known chemical shift of fat. $\phi$ and $\theta$ are other unknown systematic phase errors. When $N \geq 3$, there are two possible solutions for $W$, $F$ and two sets of corresponding values of $2\pi\Delta B_0 t_n + \theta$ [1].

## Methods and Results

Two possible values of $\Delta B_0$ are first determined by linear regression (fig.1 (a-b)). The RMS error of the correct solution tends to be lower than that of the other one where there are significant portions of both fat and water in a voxel. Therefore we choose the high SNR voxels where fat is 20-80% as the seeds for the region growing. Within the regions composed of these seeds, we use a local iteration algorithm similar to the regional iterative phasor extraction (RIPE) [2]. Instead of phasor, we extract $\Delta B_0$ directly. The initial guess of $\Delta B_0$ is the one with the lower RMS error (fig. 1 (c)). $\Delta B_0$ is flipped if the other solution is closer to the weighted local mean $\Delta_m$ than the current one. The process continues until convergence or it reaches a maximum count of iterations. Note that since $\Delta_m$ only needs to be updated where the $\Delta B_0$ is flipped in the neighborhood, the computational complexity is minimized. Then the regions are dilated gradually and the regional iteration repeated until the whole 3D image is covered (fig. 1 (d)).

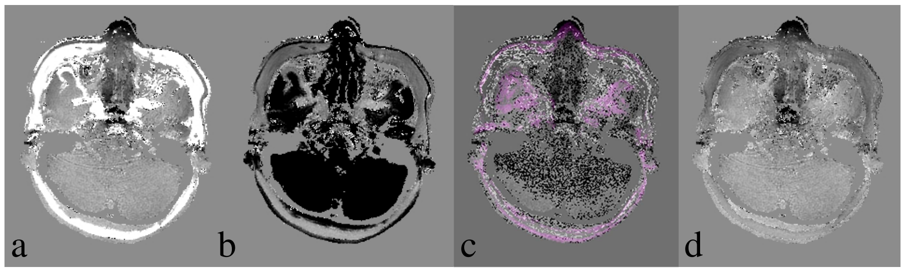


Fig 1 Field map extraction. Two sets of the solutions of $\Delta B_0$ were obtained by assuming (a) W>F and (b) F>W. (c) Initial $\Delta B_0$ formed according to RMS errors. The superimposed pink shades illustrate the starting regions (seeds). (d) The resulted $\Delta B_0$ after regional iteration and region growing. The corresponding image and results are shown in fig 2.

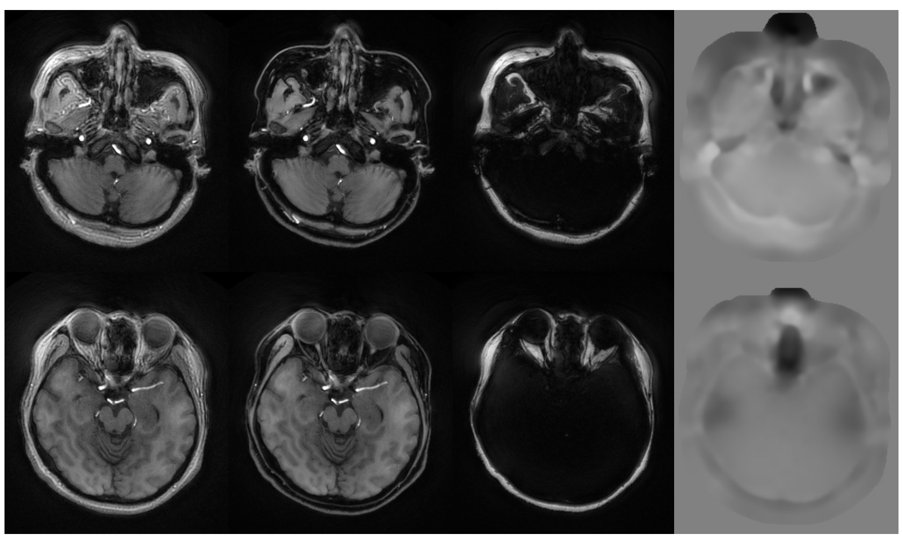

Fig 2 Results. Left to right: original image, water, fat and final field map ((-300 300) Hz). Parameters: resolution = 1 × 1 × 2 mm$^3$, ADC = 3.5 ms, TE={4.5, 5.3, 5.6} ms, TR=25 ms.

Data were acquired using a 3D stack of spirals (SOS) on a 3T Phillips Ingenia scanner at multiple TEs. After the 3D regional iteration and region-growing algorithm was applied to the coil combined images, $\Delta B_0$ was low pass filtered and extrapolated. Finally, water and fat were recalculated by linear least squares and then de-blurred [3] using the smoothed field map. The proposed algorithm consistently resolved the field map with different TE combinations. Particularly, it worked well with the low SNR field maps resulting from short minimum TE increment and the small voxel size (fig. 1-2).

## Conclusion

We have presented a robust and fast post-processing approach for field map extraction and water-fat identification from analytical solutions. The method is expected to be feasible for a wide range of $\Delta B_0$ using short, uneven TE increments.

## Acknowledgement

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**References** [1] D. Wang and J. G. Pipe, ISMRM 20: 364, 2012. [2] Q.S. Xiang, MRM 56: 572-584, 2006. [3] E. Ahunbay and J. G. Pipe, MRM 44: 491-494, 2000.