**Accelerated Water-Fat Imaging Using Restricted Subspace Fieldmap Estimation**

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**Introduction:** Water-fat separation techniques based on multi-echo methods play an important role in several clinical applications because they can reliably separate water and fat signals in the presence of B\(_0\)-field inhomogeneity. However, multi-echo methods require longer scan times as compared to single-echo imaging. Therefore, an accelerated imaging technique is desirable to reduce the length of these methods. This work proposes a new approach for water-fat separation from undersampled data acquisitions. The typical voxel-independent (VI) model is generalized to consider estimation of the entire water, fat, field map, and R2* images directly from the undersampled k-space data. An IDEAL-like algorithm is used to iterate between water-fat estimation and field map update \([1]\). Unlike previous works \([2]\), region-growing (RG) is not used for field map estimation.

**Theory:** Equation 1 presents the model that relates the undersampled k-space measurements \(k\) at echo time \(t_e\) to the unknown water image \((\rho_w)\), fat image \((\rho_f)\), and field map/R2* image \((\psi)\). The variable \(\Phi\) denotes the undersampled Fourier transform, \(d_n\) is a complex-valued quantity that represents the chemical shift of fat relative to water, and the symbol \(\otimes\) denotes point-wise multiplication.

Water-Fat Estimation: Guided by the theory of compressed sensing \([3]\), the water and fat images are estimated by including a \(\ell_1\)-penalty on their respective wavelet coefficients. Field Map Estimation: Updating the field map estimate is not straightforward since the least-squares cost function with fully-sampled data is non-convex with respect to the field map estimate. Motivated by the work of Tsao and Jiang \([4]\), this work proposes to restrict the dimension of the linear subspace, \(R\), in which the field map estimate is updated. The subspace dimension is successively increased to allow for a more accurate field map estimate, but it never reaches the full dimension of the field map image. Further, the linear functions that span the subspace are created as shifted versions of \(\text{tri}(x/a)\), where ‘\(a\)’ depends on the subspace dimension.

R2* Estimation: R2* estimation is performed after the field map has been finally estimated. The water-fat images and R2* images are iteratively estimated using an \(\ell_1\)-penalty on the water-fat estimates and a finite-difference penalty on the R2* estimate to promote a piecewise-linear result. See flowchart in Figure 1 for a summary of the approach.

**Methods and Results:** Data were collected on a 3T Signa EXCITE HDx System (GE Healthcare, Waukesha, WI) using an investigational six-echo IDEAL spoiled-gradient-echo (SPGR) sequence. The data were retrospectively undersampled using a variable-density scheme that fully-sampled the central 1/8th phase-encoding lines. Images were reconstructed using voxel-independent IDEAL \([1]\) and/or an in-house implementation of IDEAL with region-growing \([2]\), and the proposed method. All processing was done in Matlab (The Mathworks, Inc, Natick, MA).

**Discussion:** The proposed approach avoids the local minima that plague voxel-independent methods. Further, the need for region-growing/merging techniques, which rely heavily on seed pixels and connected signal regions, is avoided. By solving entire images instead of individual voxels, sparsity of water, fat, and R2* images can be exploited and the field map can be resolved in a reduced-dimensional space for accurate estimation from undersampled data.

**References:** \([1]\) Reeder et al. MRM 2005; \([2]\) Yu et al. MRM 2005; \([3]\) Candes et al. IEEE IT 2004 \([4]\) Tsao et al., ISMRM 2008.