Reconstruction of sensitivity encoded images using regulariztion and discrete time wavelet transform estimates of the coil maps

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Abstract SENSE[1] and other related techniques were proposed to accelerate image acquistion by utilizing the spatial information contained in the differing spatial profiles of array coil elements. To reconstruct aliased images, robust estimates of the sensitivity profiles of the individual channels are necessary. We demonstrate a method for deriving the coil profiles directly from array coil images. Full-FOV images from multiple receivers were filtered by multi-resoluation analysis using discrete wavelet transform (DWT) for efficient estimation of the sensitivity profiles. Additionally, Tikhonov regularization was used to stabilize the marix inversion associated with image reconstruction.

Methods In image domain unaliasing methods such as SENSE, the unfolded image $\vec{S}$ can be determined from the observed folded images from each channel $\vec{O}$, the coil maps, and the aliasing operation. This leads to a set of linear equations where **A** represents the combined effect of the aliasing operation and the coil sensitivity map.

$$\vec{O} = \begin{bmatrix} \vec{O}_1 \\ \vdots \\ \vec{O}_n \end{bmatrix} = \begin{bmatrix} A_1 \\ \vdots \\ A_n \end{bmatrix} \times \vec{S} = A \times \vec{S}$$

The subscripts refer to the different channels of the array. We solve for $\vec{S}$ using a regularized linear estimation.

To estimate the coil sensitivity profile, we use a discrete-time wavelet transform (DWT) and wavelet packet algorithm to filter a full FOV low resolution image obtained from each array channel.[2]. A Daubechies wavelet was used to implement the dyadic filter bank.

To stabilize the SENSE reconstruction, we used Tikhonov regularization [3] by incorporating a low-resolution estimate, $\vec{S}^*$, obtained from a RMS combination of the same low resolution full-FOV images reference images used to obtain the coil sensitivity maps. Regularization constraint, λ, is set to minimize the following cost function

$$\left\|A\vec{S} - \vec{O}\right\|_2^2 + \lambda\left\|\vec{S} - \vec{S}^*\right\|_2^2$$

Here we treated each frequency encoding line as an independent observation. The regularization constant λ was estimated from Generalized Cross-Validation (GCV) [4].

Images were acquired from Siemens 3T system using an MRI Devices 4 channel RF coil array and a gradient echo pulse sequence (TR/TE/flip = 293ms/4.6ms/90), slice thickness = 4mm. The low resolution but full FOV image used a 128x128 matrix and a 200mm x 200mm FOV. The half-FOV aliased image was acquired with a matrix of 64x128 and a 100mm x 200mm FOV.

Results Figure 1 shows magnitude images from each of the 4 receive channels and the DWT estimates of the coil sensitivity profile of each array element. Fig. 2 shows full-FOV reconstructed image.

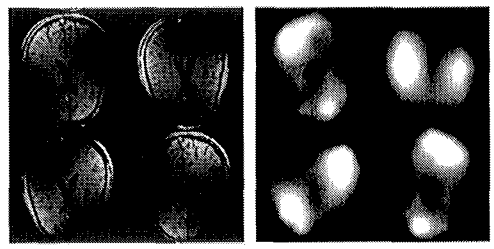

Fig. 1. Full-FOV images and estimated coil sensitivity *magnitude profiles* from four channels of the array

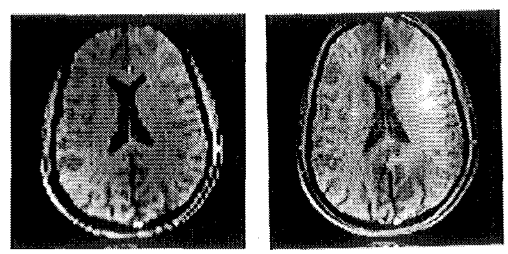

Fig. 2. Full-FOV low-resolution referernce image (left) and full-FOV SENSE reconstruction (right).

Conclusion Estimation of coil sensitivity profiles for array coil from individual channel allowed unfolding aliased images in SENSE acquisition without body coil reference images. The regularization improved the stability of the image reconstruction by automatic estimation by GCV.

References

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