Improved coil sensitivity estimation for SENSE using compressed sensing

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Introduction The performance of SENSE reconstruction is highly dependent on the accuracy of the coil sensitivity profiles used. In self-calibrated SENSE, fully sampled auto-calibration scan (ACS) lines at k-space center are used to derive the required coil sensitivity information [1]. The number of ACS lines is constrained by the limited data acquisition time, however using a small number of ACS lines may lead to Gibbs ringing that is difficult to mitigate using standard smoothing techniques [2]. We here present a compressed sensing (CS) based approach that uses a reduced number of ACS lines and incorporates all the under-sampled k-space measurements to obtain a more accurate the coil sensitivity estimate that leads to an improved SENSE reconstruction.

Theory Estimating the coil sensitivity **s** and the underlying image **f** conjointly from under-sampled k-space data set **y** has also been considered in [2] and [3], and was formulated as:

$$\{\hat{\mathbf{s}},\hat{\mathbf{f}}\} = \arg\min_{\{\mathbf{s},\mathbf{f}\}} \left(\| \mathbf{y} - \mathrm{W}(\mathbf{s}\cdot\mathbf{f}) \|_2 + \alpha\mathcal{M}(\mathbf{s}) \right) \qquad (1)$$

where W is a Fourier matrix and · denotes the element-wise multiplication. Since Eq.(1) is under-determined even in case of full data acquisition, an additional regularizing term $\mathcal{M}(\mathbf{s})$ is required for solving Eq.(1) as proposed in [2] and [3]. However such regularizing terms impose additional constraints and may reduce the fidelity of the coil sensitivity estimate.

The CS method [4] offers a new approach to tackle the above problem: instead of estimating **s** and **f** themselves, their sparse transforms **u** and **v** are estimated instead:

$$\{\hat{\mathbf{u}},\hat{\mathbf{v}}\} = \arg\min_{\{\mathbf{u},\mathbf{v}\}} \left(\| \mathbf{y} - \mathrm{W}((\Phi^{-1}\mathbf{u})\cdot(\Phi^{-1}\mathbf{v})) \|_2 + \alpha \| \mathbf{u} \|_1 + \beta \| \mathbf{v} \|_1 \right), \quad \mathbf{u} = \Phi\mathbf{s}, \quad \mathbf{v} = \Phi\mathbf{f} \qquad (2)$$

where Φ is the sparsifying transform applied on **s** and **f** for obtaining **u** and **v**. Due to the highly smooth nature of the coil sensitivity **s**, its wavelet/DCT transform is extremely sparse and hence allows Eq. (2) to be solved without additional constraints on the coil sensitivity profile.

To solve Eq.(2), we alternate between the update of the coil sensitivity estimate and image estimate of $\hat{\mathbf{u}}$ and $\hat{\mathbf{v}}$ similar to that used in [2]. Due to nature of CS, the reconstructed image and coil sensitivity may contain a lack of fine image details. Hence the image estimate from Eq.(2) may not be suitable as the final image estimate, however such drawback is very tolerable in the coil sensitivity estimate due to its high level of smoothness. In our approach, the final image is reconstructed using SENSE with the coil sensitivity estimate from Eq.(2). The procedure is illustrated in Fig.1 using a self-calibrating SENSE sampling pattern.

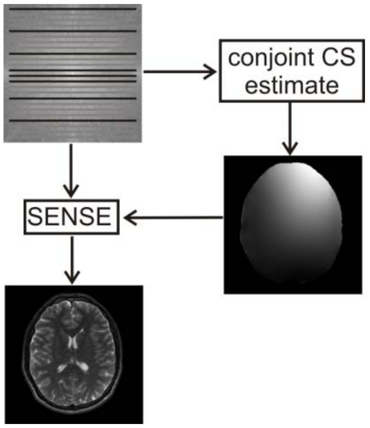

Figure 1: The overall procedure of the proposed method. The CS setup is used to estimate coil sensitivity profile using all the acquired k-space measurements.

Method A 2D T2-weighted axial brain slice was obtained (256×256) using a 1.5T GE scanner equipped with an 8-channel head coil. A SENSE sampling mask at acceleration factor of 4 was made and the central 16 lines were incorporated as ACS lines, which were also included in image reconstructions. A non-linear conjugate gradient method was used to solve Eq.(2). SENSE reconstructions with the coil sensitivity profile derived from the ACS lines and with that obtained using the proposed method are compared. In the former case, a polynomial fitting is performed on the low resolution coil sensitivity obtained.

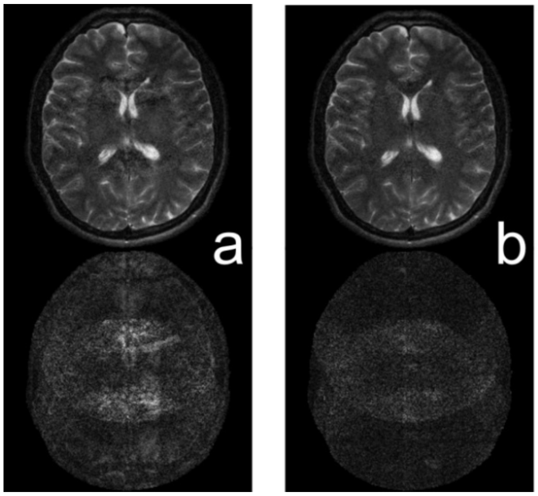

Figure 2: SENSE reconstructions using different coil sensitivity estimates.

Result and discussion The reconstruction outcome are shown in Fig.2. At the bottom, the difference maps between the SENSE reconstructions and that with full data set are shown. It is seen that SENSE reconstruction using coil sensitivity derived from the central ACS lines (Fig.2.a) features obviously higher level of residual aliasing artifacts and local noise enhancement comparing to that obtained using coil sensitivity derived from the proposed method (Fig.2.b), which benefits from the fact that all the measurements are used in estimating the coil sensitivity.

Conclusion We presented a CS based approach to improve the coil sensitivity estimate for SENSE, using a standard self-calibrating SENSE sampling pattern.

Reference [1] Mckenzie CA, et al. MRM, 2002. [2] Ying L, et al. MRM, 2007. [3] Uecker, M, et al. MRM, 2008. [4] Lustig M, et al. MRM, 2007.

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