Optimal recombination of multi-coils CSI data using image based sensitivity map

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Introduction

Parallel imaging is now routinely used to improve the SNR or to reduce the acquisition time of different MR sequence. This work addresses the problem of the optimal recombination of multi-coil chemical shift imaging (CSI) data. Along with the CSI sequence, low resolution multi-coil and body coil images are acquired and used to compute the sensitivity maps of each coil. To maximize the SNR, optimal recombination formula are derived to recombine the spectra of the different coils using this maps and taking into account the noise level of each coil. Unsuppressed water CSI spectra are also acquired to apply eddy current correction. Our method has been tested on phantom and human subjects.

Material and Method:

The CSI data (FOV=240mm, VOI=80mm, 15x15 voxels, elliptic acquisition,scheme, TE=30ms, TR=1500ms, Tacqu=3min50s) were acquired water suppressed along with unsuppressed water CSI spectra (same parameters). Spin echo images (TE=15ms, TR=300ms, FOV=240mm, 64x64 voxels, Tacqu=23s) are also acquired using the body coil as well as the multi channel antenna (TE=15ms, TR=300ms).

- **Eddy current correction**:The phase correction of each coil is estimated by fitting the water peak of the unsuppressed water CSI data. The phase signal is then unwrapped and slightly smoothed. The estimated phase is then applied on the water suppressed CSI data.
- **Sensitivity maps**: Spin echo images are used to estimate the sensitivity maps of each coil. The background is first removed by thresholding the body coil image. The background area is then reconstructed on each image by nearest neighbor interpolation. Each image is then smoothed. The sensitivity of the i-th coil is then estimated by the ratio of the smoothed image of the i-th coil to the smoothed body coil.
- **Spectra recombination:** The signal received at a given voxel from the i-th coil is modeled by $S_i = \beta_i S + \varepsilon_i$, where β_i is the sensitivity of the i-th coil, S is the ideal signal and ε_i is the noise (independent for each coil with standard deviation σ_i). A linear combination of the signal of each coil gives $\sum \alpha_i S_i = \left(\sum \alpha_i \beta_i\right) S + \sum \alpha_i \varepsilon_i$. The noise variance of the reconstructed signal $V\left(\sum \alpha_i \varepsilon_i\right) = \sum \alpha_i^2 \sigma_i^2$ and the value of the signal is driven by $\sum \alpha_i \beta_i$. As in [1], one can either maximize the signal, while keeping the noise constant, or minimizing the noise while keeping signal constant. The resolution of this two constrained optimization problem leads us to the two following formula for the recombination of the signal: $\alpha_i = \frac{\beta_i^2 \sigma_i^{-2}}{\sum \beta_k^2 \sigma_k^{-2}}$ or $\alpha_i = \frac{\beta_i^2 \sigma_i^{-2}}{\sqrt{\sum \beta_k^2 \sigma_k^{-4}}}$. These formulas are a generalization of the formula of [1] (found by taking the σ_i constant).

Results and Discussion

Our reconstruction has been tested on a phantom and two human. Result of our method has been compared with the Siemens reconstruction. On Fig. 1, one can see the results of siemens reconstruction and our method on a phantom acquired on a Siemens Verio 3T scanner using 4 coils. One can see that our reconstruction seems more affected by the reconstruction inhomogeneity (homogeneity map is given by the intensity of the resulting water peak). This is at the expense of the additional low resolution (and low acquisition time) images not used by Siemens. An example of reconstructed spectrum is given Fig 1d and Fig 1e. One can see that our signal seems cleaner with finer peak. The SNR measured for these to spectra are 35 for our reconstruction and 18 for Siemens.

Our method has also been tested on human subjects on a Siemens Avanto 1.5T MR scanner using 4 coils. Fig. 2 shows an example of our reconstruction (SNR=120) versus the recontruction of the manufacturor (SNR=91).

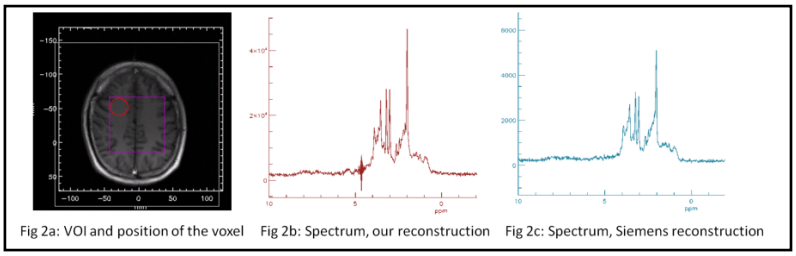

Fig 2a: VOI and position of the voxel | Fig 2b: Spectrum, our reconstruction | Fig 2c: Spectrum, Siemens reconstruction

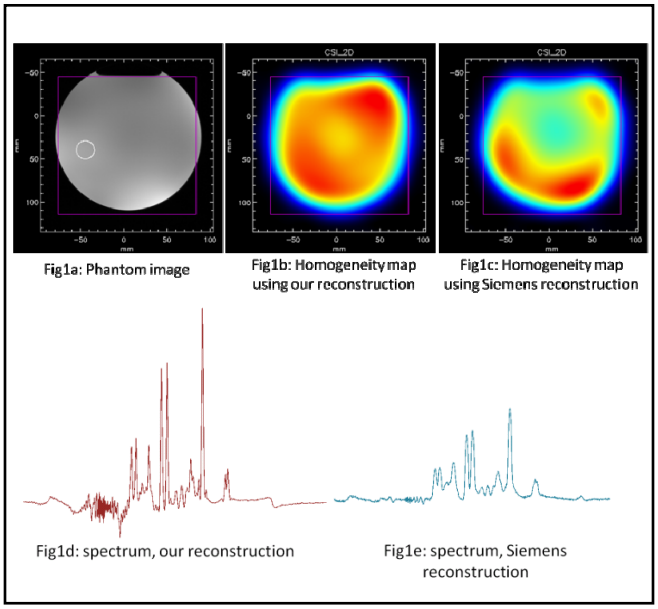

Fig1a: Phantom image | Fig1b: Homogeneity map using our reconstruction | Fig1c: Homogeneity map using Siemens reconstruction

Fig1d: spectrum, our reconstruction | Fig1e: spectrum, Siemens reconstruction

Conclusion:

A method for the recombination of CSI data has been presented in this work. The first results are promising as the maps derived from the spectra seems to be more homogeneous and the SNR seems to increase as compared with manufacturor recombination. Further evaluation needs to be done to validate our method with more subjects, different acquisition sequences, or other organs. However, on a 3T MR scanner with more coil, we believe that the use of image based SNR optimization recontruction should be even more efficient .

Reference:

[1] Wright etal, 1997, NMR in Boimed.
[2] Le Fur etal, 2010, MAGMA