Iterative MR Image Reconstruction Using Sensitivity and Inhomogeneity Field Maps

Bradley SUTTON[1], Jeffrey A. FESSLER[2], Douglas NOLL[1]

[1]University of Michigan, Dept. of Biomedical Engineering, Ann Arbor, MI USA; [2]University of Michigan, Electrical Engineering and Computer Science, Ann Arbor, Michigan USA;

Introduction

Standard Fourier reconstruction of MRI data relies on the Fourier transform relation between acquired k-space data and the image as described by the signal equation. This relationship does not hold, however, in the presence of inhomogeneities of the magnetic field. The Fourier reconstruction also does not handle data from non-Cartesian k-space sampling patterns, such as spirals, and information from coil sensitivity maps in parallel imaging experiments. In nonparallel imaging schemes, many methods have been proposed to compensate for field inhomogeneities when a nonrectilinear k-space scanning protocol is used [1,2,3,4,5]. Most of these rely on the assumption of a smoothly varying field map. Parallel imaging methods such as SENSE [6] have enjoyed increasing popularity over the last few years due to decreased scan times, despite suffering from the need for efficient reconstruction algorithms when non-Cartesian k-space trajectories are used. In this abstract, we use the readily available information of an inhomogeneity field map and sensitivity maps for the coils to perform iterative least squares image reconstruction in a spiral SENSE experiment.

Theory

The signal received by coil γ, $y_\gamma(t)$, is given by,

$$y_\gamma(t)=\int m(\underline{r})s_\gamma(\underline{r})e^{-i2\pi(k_{\underline{r}}(t)\underline{r}+\omega_o(\underline{r})t)}d\underline{r}+n_\gamma(t) \quad (1)$$

where $m(\underline{r})$ is a function of the proton density, $s_\gamma(\underline{r})$ is the sensitivity map for coil γ, $\omega_o(\underline{r})$ is the off-resonance frequency, and $n_\gamma(t)$ is the noise. If the object to be imaged is discretized, then Equation 1 becomes, $y_\gamma=\tilde{A}S_\gamma m+n_\gamma$.

The entries in $\tilde{A}$ are given by, $a_{jl}=e^{-i2\pi(k_{\underline{r}}(t_j)\underline{r}_l+\omega_o(\underline{r}_l)t_j)}$, and S_γ is a diagonal matrix with the coil sensitivity values on the diagonal. Stacking this system of equations for each coil, we get, $y=Am$. We then solved the image reconstruction problem in a least-squares sense using the conjugate gradient method.

Methods

Phantom data was collected using two 5 in. coils with two interleaved spirals giving a fully sampled k-space. Data from two echo times was collected to determine the fieldmap. The full FOV data for each coil was used to construct its sensitivity map and determine the inhomogeneity field map. One of the interleaves was discarded and the image was reconstructed using the subsampled k-space and the field and sensitivity maps.

Results

Figure 1 shows the standard discrete Fourier transform reconstruction results for one coil when the coil sensitivity information was not used. Figure 2 shows the fieldmap employed in the iterative reconstruction. The results of the proposed iterative reconstruction are shown in Figure 3. This is after 10 iterations taking 8 min. on a Sun Ultra10 computer. The normalized mean-squared error for the proposed iterative method compared to the image using both interleaved spirals was 3%.

Discussion

The algorithm presented here is useful for reconstructing non-Cartesian MRI data such as spiral SENSE data in the presence of inhomogeneities. In time-series studies such as those in fMRI, the field map and sensitivity maps need only be determined once, during baseline scans. Current methods to correct field inhomogeneities, such as conjugate phase, rely on smoothly varying fieldmaps, an assumption not used in this method.

References

[1]TB Harshbarger, DB Tweig. *IEEE Trans. Med. Imag.,* 18(3):196-205, 1999.
[2]YM Kadah, X Hu. *Mag. Res. Med.,* 38:615-627, 1997.
[3]YM Kadah, X Hu. *IEEE Trans. Med. Imag.,* 17(3):362-370, 1998.
[4]Noll, et al. *IEEE Trans. Med. Imag.,* 10(4):629-637, 1991.
[5]Noll, et al. *Mag. Res. Med.,* 25:319-333, 1992.
[6]Pruessmann, et al. *Mag. Res. Med.,* 42:952-962, 1999.

This work was supported in part by a Whitaker Foundation Graduate Fellowship and CBER, Univ. of Mich.

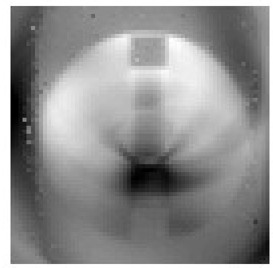

Figure 1: Standard reconstruction from one coil.

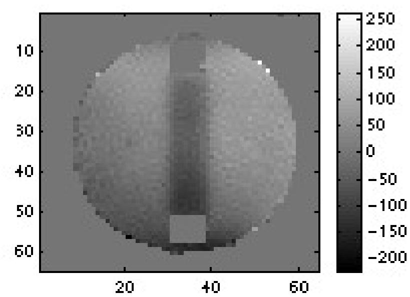

Figure 2: Field inhomogeneity map used for iterative reconstruction.

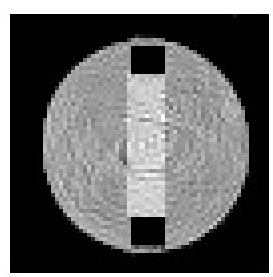

Figure 3: Proposed iterative reconstruction.