Dynamic Field Map Estimation Using a Single Spiral In/ Spiral Out Acquisition

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Synopsis Single-shot acquisitions and high field strengths used in functional MRI scans make it sensitive to main magnetic field inhomogeneities. The ability to measure and compensate for these inhomogeneities on an individual time-point basis may lead to better image registration, motion compensation and correction for dynamic respiratory-induced variations in the field and main field drift during a study. We propose a simultaneous estimation scheme whereby the field map and field-corrected image are estimated at each time point using a single spiral in/ spiral out acquisition. Simulation and human results are presented that compare our approach to conventional field map estimation.

Introduction Current fMRI studies use high field strengths and single-shot acquisitions, both of which make the scans sensitive to magnetic field inhomogeneity effects. The standard method to measure the field map is to acquire 2 scans at different echo times and divide the phase difference between the 2 images by the difference in echo times **[1]**. Recently we have proposed a simultaneous estimation scheme whereby a physical model of the signal equation is used in an iterative method to estimate the undistorted image and its associated, undistorted field map **[2,3]**. The signal equation, with field inhomogeneity effects, is included in a cost function which compares the expected data to the acquired data and also includes regularization terms. The algorithm proceeds by alternating between updating the image using the conjugate gradient method and updating the field map using gradient descent.

In this work, we propose to use the simultaneous estimation algorithm in combination with a spiral in/ spiral out pulse sequence to estimate an undistorted image and field map from one acquisition. The spiral in/ spiral out acquisition does not reduce the number of slices per TR of a spiral out pulse sequence **[4]** and should not reduce the scan rate of current studies. Our method is compared to the standard field map estimation scheme where the spiral in and spiral out images are reconstructed separately to produce a field map from their phase difference.

Methods Simulations and experimental data were run with a spiral in/spiral out sequence (FOV 24 cm, matrix size 64, TE 25 ms, 1 ms gap between spiral in/ spiral out). Simulations were run using a 256x256 object and field map and adding noise to the data to give an SNR of 100. Our method used the simultaneous estimation algorithm described above, initialized with a zero field map. In practice, initializing the field map with that from the previous time point may save considerable computation time. For the human brain data, an extra acquisition of a short echo-time, 4 shot spiral at 2 echo times was acquired to give a good estimate of the true field map.

Results Figure 1 shows the RMS error in Hz over iteration for the proposed simultaneous estimation method. As can be seen in Figure 2, the standard field map estimation from the separate spiral in/ spiral out images suffers from the fact that through-voxel gradients in the field map change the effective echo time for each image pixel and this effective echo time differs for the spiral in and spiral out images. Our method benefits from using the information over the time of acquisition, instead of just one echo time. Figure 3 shows the results from human brain data. The standard field map estimation method suffers from effective echo time, where our simultaneous estimation method gives results similar to that of the extra acquisition. The resulting simultaneously estimated image is also shown.

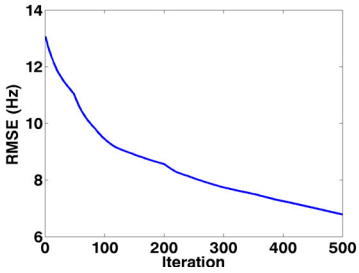

Fig. 1: Convergence curve for simultaneously estimated field map simulation.

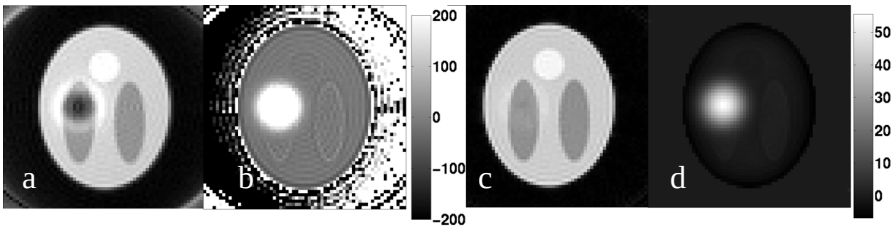

Fig. 2: Simulation results: a) uncorrected spiral out image. b) Standard estimate of field map in Hz from spiral in/ spiral out. c and d) simultaneously estimated image (c) and field map in Hz (d).

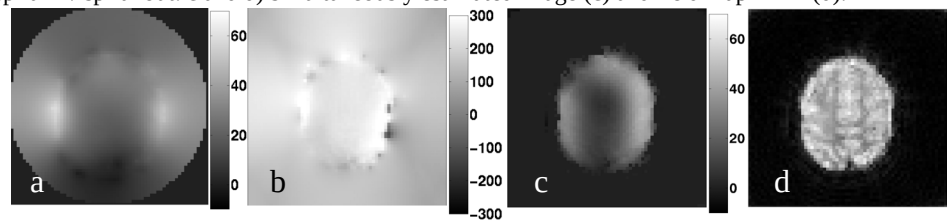

Fig. 3: Human brain results: a) Standard field map from extra acquisition. b) Standard estimate of field map in Hz from spiral in/ spiral out. c and d) simultaneously estimated field map in Hz (c) and image(d).

Conclusion Estimating a field map and corrected image from a single acquisition allows field correction to occur despite motion, respiratory-induced field variations, or main field drift. Such corrections may improve image registration during a functional study. We have shown that a spiral in/ spiral out pulse sequence combined with our simultaneous estimation algorithm provides accurate estimates of the field map and field-corrected image with data from a single acquisition.

References **[1]** Schneider and Glover. *Mag. Res. Med.*, 18:335-347,1991. **[2]** Sutton, et. al. *Proc. 10th ISMRM.*, 737,2002. **[3]** Sutton, et. al. *Proc. 10th ISMRM.*, 1323,2002. **[4]** Glover and Law. *Mag. Res. Med.*, 46:515-522,2001.