A simultaneous estimation of field inhomogeneity and R2* maps using extended rosette acquisition

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ABSTRACT
The field inhomogeneity and R2* map played an important role in many MR studies, therefore demanding fast and accurate ways to measure those parameters. In this work, we suggest a simultaneous estimation of both parameters using an extended rosette acquisition. By generating a series of sub-images from the extended data set, both parameters could be successfully estimated. A simulation study shows that the suggested method is more accurate than the conventional methods, and also requires considerably less scantime. A preliminary phantom experiment result is also shown.

INTRODUCTION
The spatial information of field inhomogeneity (field map) has been used in off-resonance artifact correction methods on MR images[1-3]. Most of them estimated the field map from the two-point method which calculates field map from the phase of two different echo images[1-3].

In BOLD studies, the spatial information of R2* (R2* map, or equivalently T2* map) varying in time can be utilized to quantitate physiological changes in brain by itself, or to optimize the functional contrast[4]. To quantitate the R2* map, multiecho imaging methods have been used in several studies[4-5].

However, the multiecho imaging methods require many (5~12) extra echo images, therefore lengthening the total scan time to get one R2* map. To reduce the scan time, we suggest a novel way to simultaneously estimate field map and R2* map using an extended rosette acquisition with less amount of data than the standard multiecho methods, therefore increasing the time resolution of R2* map.

In this work, a simulation result is presented for a comparison with the conventional methods, followed by a preliminary result of a phantom experiment.

METHODS
Figure 1 shows the magnitude of a data set collected using 150% extended rosette acquisition (2.5 times single shot). Since the trajectory has an oscillatory behavior, one can easily extend the data acquisition to revisit earlier k-space locations as long as it provides acceptable SNR. From this extended data set, we can choose one full shot amount of data from any location by windowing as seen in Figure 1. As we move the window location with a step size in time (Δt), we can reconstruct a time sequence of N subimages of the object using a weighted least square conjugate gradient method with a quadratic smoothness penalty (QPWLS-CG)[6]. By examining the phase and magnitude of each voxel in time course, we can estimate the field map and R2* map using linear regression.

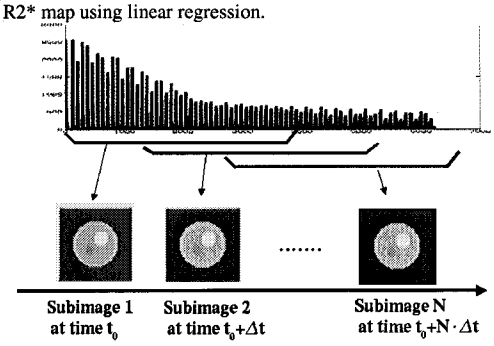

Figure 1. Sliding window reconstruction to get a set of subimages

However, since each of the subimages share some of the data (50% in this work) with the adjacent ones and the field map decay occurs during the acquisition, applying linear regressions to the phases of subimages introduces more error in the field map estimate than the standard two-point method. To reduce the error, an iterative method was used as follows; The current estimate of field map was used to correct susceptibility artifact of each subimages, then those subimages were used to extract remaining field map component by linear regression. This remaining component of field map was added to the current estimate of field map to generate the next estimate. The field map was smoothed at each iteration using QPWLS-CG .
Following the field map estimation, the R2* map was calculated from the resultant susceptibility artifact corrected subimages. Pairs of non-overlapping subimages were chosen, and N/2 R2* maps were calculated from log of the images. The R2* map was acquired by averaging those pair-wise R2* maps.

A simulation study was conducted on a synthesized object (64x64) with a reference field map (min:-14Hz, max:9.94Hz) and a reference T2* map (min:33.5ms, max:50ms). The human subject experiment was conducted using 3.0T Signa-LX scanner (GE Medical Systems, Milwaukee, WI). The rosette trajectory had the following parameters. $\omega 1$=1024.6Hz, $\omega 2$=204.9Hz, max slew=167.47mT/m/ms, max gradient=1.89G/cm, FOV=20cm, Resolution=5mm with two interleaves. The scan parameters were, TE=6.0 ms, TR=1000 ms, total data acquisition time=43.9ms/interleave, flip angle=90° and slice thickness=3mm.

RESULT AND DISCUSSION
Figure 2 shows the simulation and phantom experiment results. The normalized mean square error (NMSE) was measured in the region of support, and the images shown were masked and normalized.

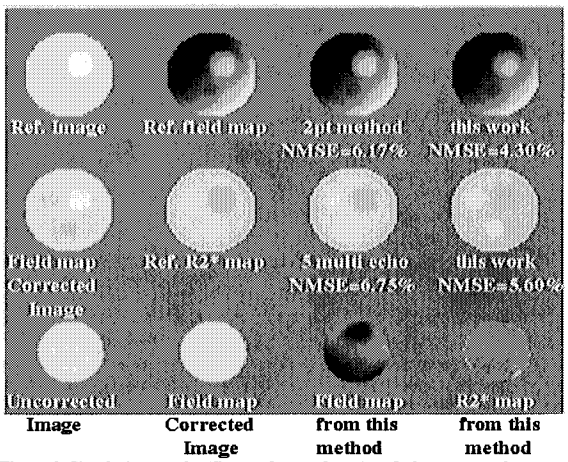

Figure 2. Simulation results (first and second row) and phantom results (third row)

The suggested method provided enhanced accuracy in the estimates of field map and R2* map from relatively short amount of data acquisition (2.5 times single shot). Increasing step size of data window will reduce redundancy in each subimage to improve the accuracy of the estimates, but it will require more scan time. The future work will include designing an optimum rosette trajectory for the best spatial resolution with moderate slew rate , and a post-processing of the estimates based on a more accurate signal model to provide better accuracy with even less scan time. With these improvements, this method can be used in BOLD studies to provide R2* maps at significantly higher rate, also increasing the detectability of BOLD signal.

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