Improved Inversion Recovery Image Reconstruction from Phased-Array Data Using a Markov Random Field Model

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INTRODUCTION: Inversion recovery (IR) pulse sequences have been widely used for contrast manipulation such as fat or fluid suppression but its promise for enhanced T1 tissue contrast has rarely been achieved in practical applications. This is mainly because the conventional magnitude reconstruction eliminates the polarity information, reducing the dynamic intensity range from [$-M_o$, M_o] to [0, M_o]. In addition, the scan time is still rather long making it impractical in some clinical applications. Parallel imaging methods using phased-array coils, such as SENSE has been combined with phase corrections to provide phase-sensitive inversion recovery (PSIR) images while shortening the imaging time [1,5]. However, a reference scan is needed for coil sensitivity and background phase estimation, which reduces the efficiency of the parallel imaging and may make the method sensitive to bulk-object motion. This abstract presents an improved method which uses a Markov Random Field model for phase correction which is compatible with SENSE and does not require an additional calibration scan. Brain imaging experiments show that this method can provide enhanced tissue contrast while reducing scan time.

METHOD: As illustrated in Fig. 1, the k-space data in the proposed method are acquired in variable densities. In addition to uniformly subsampled phase coding lines (reduction factor R) as in SENSE, extra M central lines are acquired. Then the coil sensitivities are estimated by dividing low resolution coil images from the M lines with a sum-of-squares image. Using such sensitivities in the SENSE reconstruction, the final image has essentially no phase information. Then an individual coil images I_i, is generated for each of the N coils by modulating the SENSE reconstruction with the corresponding complex coil sensitivity map. Note that in IR imaging, $I_i(x,y)=|I_i(x,y)|\exp\{j[\theta(x,y)+s(x,y)]\}$, where $|I_i(x,y)|$ is the magnitude, $\theta_i(x,y)$ is the background phase due to hardware imperfection, and $s(x,y)$ is the intrinsic phase, either 0 or π, corresponding to the positive and negative magnetizations at the time of acquisition. To obtain the polarity information, $\theta_i(x,y)$ needs to be estimated and removed from the image. To do so, a statistical model based on Markov Random Field is used to estimate $\theta_i(x,y)$ in a coil-by-coil fashion. Technical details of the estimation algorithm have been described elsewhere [3,4]. After the phase is removed, a real coil image is obtained, which contains both positive and negative values, and a final reconstruction can be produced by simply summing up all real coil images from N coils.

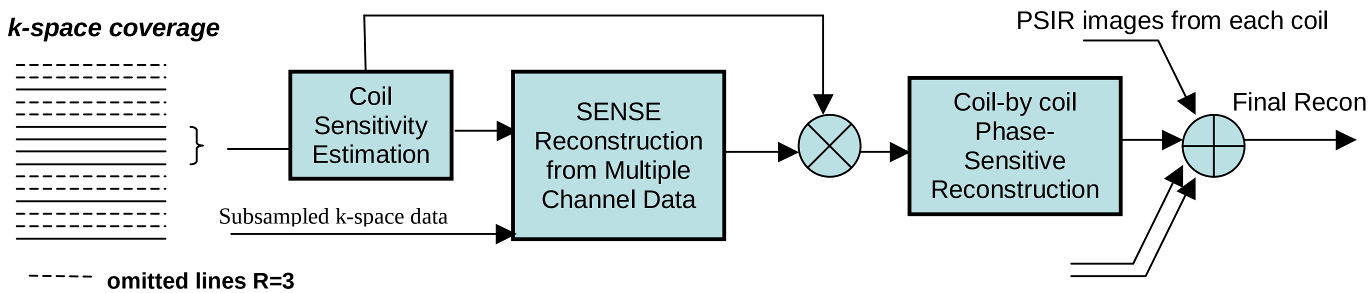

Figure 1. Illustration of the data acquisition and image reconstruction algorithm of the proposed method.

RESULTS: Brain imaging data of a healthy volunteer were acquired on a 1.5 Tesla scanner using an 8-channel head coil with 256×256 data matrix, TR=2 s and TI=300 ms. Variable density data are retrospectively simulated. Figure 2(a) shows a PSIR reconstruction using an additional 256×256 reference scan to estimate the background phase and the full k-space data (i.e., R=1). Figure 2(b) shows the PSIR reconstruction using the proposed method where the k-space data is subsampled with R=2 and M=32, without additional calibration scans. Figure 2(c) shows the conventional sum-of-squares reconstruction without phase correction. Note the contrast improvement of PSIR reconstructions over the conventional reconstruction. The improved tissue contrast makes it acceptable to use the reduced imaging time, overcoming the reduced SNR associated with parallel imaging. The image reconstruction and processing time per slice is less than 8 s on a Pentium 4 computer with 1 GB memory.

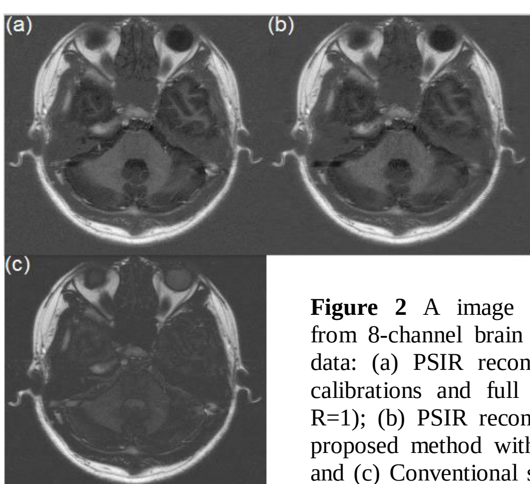

Figure 2 A image slice reconstructed from 8-channel brain inversion recovery data: (a) PSIR reconstruction with full calibrations and full k-space data (i.e., R=1); (b) PSIR reconstruction using the proposed method with R=2, and M=32; and (c) Conventional sum-of-squares real reconstruction without phase correction.

DISCUSSION: We have developed an improved phase-sensitive inversion recovery method using parallel phased-array coils. By using adaptive coil sensitivity estimation and using a Markov Random Field model to correct the background phase, it is possible to perform phase-sensitive reconstruction without reference scans. Simulation results using in vivo brain imaging data have shown that the scheme is capable of reconstructing images with enhanced tissue contrast in reduced scan time. The improved speed and robustness of the method should make it useful for clinical applications. Collecting variable density k-space data using fast spin echoes requires careful arrangement of the phase encoding order to avoid artifact and phase errors. This is an issue that will be addressed in our future investigations.

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