Updating Pre-scan Sensitivity Maps with the Minimum Number of ACS lines

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Introduction

Accurate sensitivity maps are critically important to the quality of SENSE reconstruction [1]. Pre-scan data has been widely used to generate sensitivity maps. This approach has advantages over in-line calibration methods because it allows for the acquisition of reference data from both the body coil and the phased array coil elements, enabling automatic intensity correction and minimizing the total scan time. However, one potential problem when using data from a pre-scan is misregistration between the pre-scan and the actual SENSE acquisition due to subject motion. To reduce the misregistration error while taking advantage of the pre-scan approach, it is proposed to add a minimum number of auto-calibration signal (ACS) lines to the target acquisition in order to correct the misregistered sensitivity maps. In vivo experiments using as few as 3 ACS lines for sensitivity map correction resulted in significant improvement in the subsequent SENSE reconstruction.

Theory

In the proposed method, an initial SENSE reconstruction is generated using the original sensitivity maps S_i from the pre-scan data. Artifacts caused by misregistration can be detected using the normalized mutual information [2] between the resulting image and the low-resolution pre-scanned body coil image. If misregistration is detected, the initial SENSE image is projected back to *k*-space for each individual coil (by multiplying the original sensitivity maps). In the next step, the acquired lines (including ACS) are used to replace the reconstructed *k*-space lines at the corresponding locations. With the updated individual coil images I_i from the updated full *k*-space data, corrected sensitivity maps can be generated as follows: $S_i^{new} = I_i / (\sum_j I_j S_j^*)$, where * denotes complex conjugate. Due to the noise and artifacts in the initial SENSE reconstruction, a smoothing constraint is applied to the sensitivity maps during re-calculation. Due to the slow spatial variation of sensitivity maps, most of their information lies near center of *k*-space. Therefore as few as 3 ACS lines are sufficient to correct the sensitivity maps for most applications.

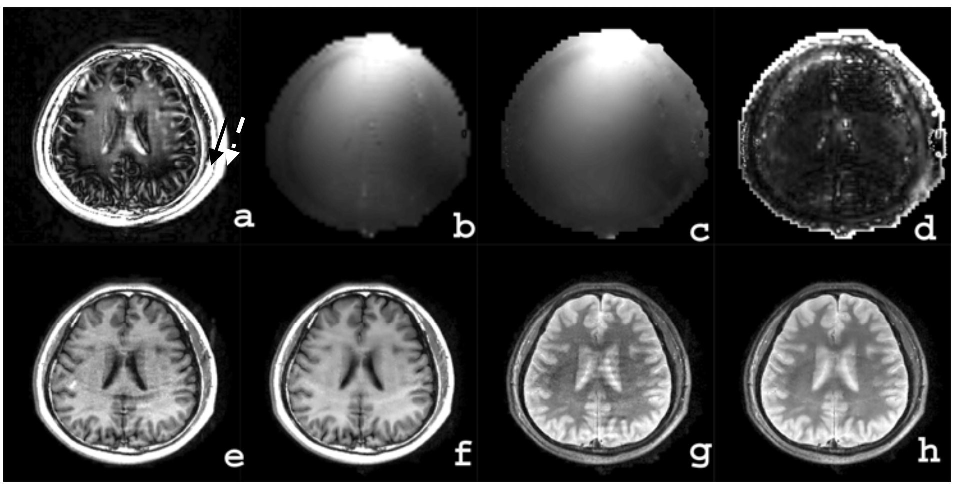

Fig1. a. Difference between bodycoil image and target image; b. initial sensitivity map of channel 1; c. updated sensitivity map of channel 1; d. difference between Figs. 1b) and 1c); e. and g.: initial reconstruction with net acceleration factor 3.8; f. and h. reconstruction with the updated sensitivity maps

Methods

Brain data sets were acquired on a 3.0T Achieva scanner (Philips, Best, Netherlands), using an 8-channel head coil (Invivo, Gainesville, FL). With the same FOV (230x230 mm^2), pre-scan data for sensitivity maps, with matrix size of 64x64, and high resolution data, with matrix size of 256x256, were acquired. Before the high resolution data were acquired, the volunteer moved his head which introduced a misregistration between the data sets. Two sets of high resolution data were collected. An IR sequence, with TR/TE=2000/20 ms, was used for both data sets. Two different inversion times were used to separately suppress gray matter (TI = 800 ms) or fat (TI = 180 ms). The TI = 800 ms IR sequence was used to acquire the pre-scan data. Phase encoding direction was anterior-posterior. The fully acquired data was artificially under-sampled at R = 4, including 3 additional ACS lines, to simulate the partially parallel acquisition. The net acceleration factor was 3.8. The full *k*-space data set was used to generate the reference image for the calculation of root mean square error (RMSE). Minimization of L_2 norm is used as the constraint term when smoothing the sensitivity maps. One extra SENSE reconstruction was processed with the updated sensitivity maps.

Results

Fig. 1a is the difference between bodycoil image and the target image, which demonstrates the translation. The white dashed and black solid arrows show the right edge of body coil image and the target image respectively. **Fig. 1b** gives the sensitivity map of channel 1 calculated from the pre-scan data. **Fig. 1c** gives the updated sensitivity map of channel 1 using the proposed method**.** The difference between Figs. 1b and 1c can be seen in **Fig. 1d**. With the use of the updated sensitivity maps, the RMSE in reconstruction were reduced from 8.9% (**Fig. 1e**) and 10.4% (**Fig. 1g**) to 4.9% (**Fig. 1f**) and 6.3% (**Fig. 1h**).

Discussion and Conclusion

The purpose of this method is to correct for misregistration between pre-scan sensitivity maps and the acquired data. The experiments demonstrated that with as few as 3 additional ACS lines, the image quality can be efficiently improved with the corrected sensitivity maps. By taking advantage of a pre-scan, the proposed method can achieve a higher net acceleration factor than in-line calibration techniques and the intensity homogeneity correction is enabled. The proposed method needs only one additional SENSE reconstruction with the updated sensitivity maps. Further iterations do not significantly improve image quality. In conclusion, an efficient method to correct misregistered sensitivity maps, which is a major source of error for SENSE imaging, has been proposed and demonstrated.

References

[1] Pruessmann K. P. et al. *Magn Reson Med* 1999; 42:952-962. [2] Guiasu, Silviu (1977), Information Theory with Applications, McGraw-Hill, New York.