Fast Non-iterative JSENSE: From Minutes to a Few Seconds

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Introduction

Joint image reconstruction and sensitivity estimation in SENSE (JSENSE) [1~3] has been proposed to improve image quality when acceleration factor is high. All of the reported techniques update sensitivity maps and the to-be reconstructed image iteratively with the constraint that the sensitivity maps are smooth. There are two practical issues in these iterative methods: 1) The computation time may be as long as several minutes [1, 2] ; 2) It is hard to find an optimal termination condition to avoid divergence [4]. Hence, these methods do show the feasibility of JSENSE, but are difficult to be applied to routine clinical use. In this work, a fast non-iterative JSENSE is proposed, which uses a pseudo full *k*-space data set to update the sensitivity maps. Using this scheme, the calculation time for the updated sensitivity maps can be reduced to less than 2 seconds for a 256×256×8 data set. The effectiveness of the proposed method is shown for updating sensitivity maps from either self-calibration signal or pre-scanned image.

Theory

A pseudo full *k*-space data set is used to update sensitivity maps. The pseudo full *k*-space data set is produced by using the denoised initial reconstruction, initial sensitivity maps, and all of the acquired *k*-space data. Due to the denoising of the initial reconstruction, the noise/artifact level in the pseudo full *k*-space is low. Also, because this pseudo full *k*-space data set contains all of the acquired *k*-space data, it provides maximum possible information for updating the sensitivity maps. Based on this thought, we propose to produce a calibration image (Fig. 1e) by denoising the reconstruction (Fig. 1c) which was done with the initial sensitivity maps (Fig. 1b). Since information regarding the noise distribution in the combined image can be provided by the g-factor map for the initial SENSE [5] reconstruction, the denoising can be guided by g-factor [6]. The calibration image can then be projected back to *k*-space for each individual channel using the initial sensitivity maps to produce a set of reconstructed full *k*-space data. Part of this reconstructed *k*-space data can then be replaced with the known acquired *k*-space data in order to generate a pseudo full *k*-space. With this pseudo full *k*-space data set, a new set of updated sensitivity maps can be calculated (Fig. 1f). Final reconstruction (Fig. 1g) is the result by SENSE with the updated sensitivity maps.

Methods

One set of brain data was acquired on a 3.0T Achieva scanner (Philips, Best, Netherlands), using an 8-channel head coil (Invivo, Gainesville, FL). IR sequence was used with the following scan parameters: TR/TE=2000/20 ms, TI = 800 ms. Phase encoding (PE) direction was anterior-posterior. 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. The fully acquired data set was artificially under-sampled with R = 4 to simulate the partially parallel acquisition. Three schemes were used to produce the initial sensitivity maps: 1) central 24 PE lines for self-calibration; 2) pre-scanned data; 3) pre-scanned data with rigid motion (2 pixels along LR direction and 2 pixels along AP direction). Net acceleration factors for these three schemes were 3.1, 4, and 4 respectively. For comparison, separate images were reconstructed using conventional SENSE [5], and the proposed new non-iterative JSENSE. The acquired full *k*-space data was used to generate the reference image for root mean square error (RMSE) calculation.

Results

The total calculation time for updating sensitivity maps was less than 2 seconds: 1 second for image denoising (from Fig. 1c to 1e), and 0.9 second for Fast Fourier transforms to project to and back from *k*-space. Fig. 1 shows the result using the self-calibration scheme. As shown by the difference maps (Figs. 1d and 1h), the RMSE was dramatically reduced due to the application of the updated sensitivity maps. In Fig. 2, the performance of the proposed method for three different schemes of initial sensitivity maps are presented by the enlarged and cropped images. It shows that the proposed method works robustly for both self-calibration (Fig.2a,d) and pre-scan scheme (Figs. 2b,e and 2c,f). Even if the pre-scanned sensitivity maps were misregistered (Figs.2c, f), the proposed method can still reduce noise/artifact level. The RMSE was reduced from 9.7% (Fig. 2c) to 8.4% (Fig. 2f) in this example.

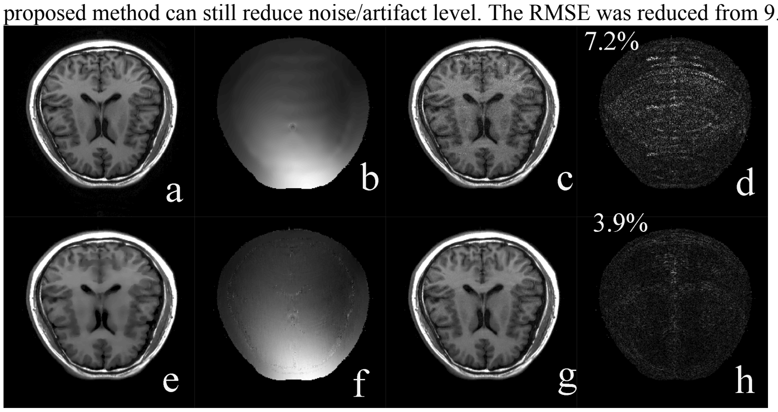

Figure 1 Results using self-calibration scheme. a) The reference image; b) and f) The sensitivity map of channel 1 before and after the update respectively. e) the calibration image from denoising the initial reconstruction c). g) The final reconstruction with updated sensitivity maps. d) and h) The error map of c) and g) respectively.

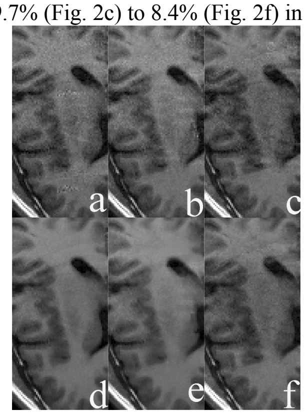

Figure 2. These three columns are for three different schemes for initial sensitivity maps. The two rows are for results with initial and updated sensitivity maps.

Discussions and Conclusion

The proposed non-iterative JSENSE reduces noise/artifact level in sensitivity maps by smoothing the calibration image and provides extra sensitivity information by using all of the acquired *k*-space data. Since the sensitivity maps are re-calculated using pseudo full *k*-space, no smoothness regularization or iteration is necessary for solving an underdetermined system. Therefore, the processing time can be reduced from minutes to less than 2 seconds for a 256×256×8 data set in Matlab. An extra advantage of the proposed method is that it can be applied to SENSE with pre-scanned sensitivity maps, which is not reported for existing techniques.

References

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