Correction of Intensity Inhomogeneity in Multi-spectral MRI

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Introduction

MR images can be acquired by multiple receiver coil systems to improve SNR and to decrease acquisition time. In the cases when coil sensitivities are unknown, the sum-of-squares (SoS) reconstruction algorithm [1] is typically applied. The intensity of the SoS reconstructed image is modulated by a spatially variable function due to the non-uniformity of coil sensitivities. Intensity inhomogeneity correction of SoS reconstructed images is mandatory when quantitative analysis and/or tissue segmentation is required. In this study, we have proposed a technique to estimate and correct the coil intensity inhomogeneity in multi-spectral MR images.

Method

Given $C1_i$, $C2_i$,… CM_i i=1,…N are individual coil images from a multi-contrast study consisting from M different contrasts and $C1_{SoS}$, $C2_{SoS}$…CM_{SoS} are the corresponding SoS images arranged in the order of decreasing SNR. The proposed intensity inhomogeneity correction technique consists of the following steps:

1. Obtain unbiased filtered SoS images

The removal of noise bias is mandatory for low SNR images to improve contrast between tissue types. The bias is removed by using the post processing approach suggested in [2]. Then, the unbiased images are processed by anisotropic diffusion filter [3] to suppress image noise. Due to the availability of multi-contrast images, a vector form of the filter can be applied. This form of the filter improves the SNR as well as the structural detail in low SNR images. The unbiased filtered SoS images obtained in this step are denoted by Ck_{SoSf} where k=1,….M.

2. Obtain a mask I_D of dominant tissue

The ratio image R between images $C1_{SoSf}$ and $C2_{SoSf}$ is calculated and used to identify the image area occupied by the dominant tissue type. The mask of the dominant tissue I_D is calculated as follows:

$$I_D = \begin{cases} 1 & 0.9 \cdot h < R < 1.1 \cdot h \\ 0 & otherwise \end{cases}$$

where h is equal to the image intensity value corresponding to the peak of the image intensity distribution (histogram).

3. Polynomial fit to the dominant tissue region

Assuming that the coil sensitivity profile can be described by a smoothly varying function, a third-order polynomial is fitted to each individual unbiased coil image in the regions occupied by dominant tissue in the highest SNR contrast images, to obtain the coil sensitivity maps S_i.

4. Sensitivity compensation

The final images are obtained by correcting each of the contrast images Ck_{SoS} by the SoS image S_{SoS} of the coil sensitivity maps S_i:

$$Ck_{corrected} = Ck_{SoS} / S_{SoS} \quad \text{where } k=1,\ldots.M.$$

The correction is done on SoS image instead of individual coil images to prevent noise amplification in the regions of low values of coil sensitivity profiles.

Results

The method was tested on MR images acquired on a 1.5 Tesla GE SIGNA Lx 8.4 MR scanner (GE Medical Systems, Waukesha, WI) and a 3 Tesla Siemens TRIO MR scanner (Siemens Medical Solutions, Erlangen, Germany). Figure 1 presents the results for correction of proton density (PD)-T1-T2-weighted images of carotid arteries acquired by a triple contrast technique [4] on GE 1.5 T. A specially designed bilateral four-channel phased array coil was used in this study. Figure 2 presents the results of the application of the proposed technique to correction of PD image acquired by dual contrast (PD-T2) turbo spin echo sequence using an eight-channel head coil on the Siemens 3 T. The histograms of the original as well as the intensity corrected PD images is presented to show that the technique used narrows the image intensity distribution as expected in the case of successful intensity inhomogenity correction.

Discussion and Conclusions

The technique for compensation of intensity inhomogeneity in multi-spectral MRI has been developed. This method is computationally efficient as well as completely automated. The processing time is less than 2 seconds per slice using a mid range PC. The technique can also be applied for correction of intensity inhomogeneity in a single contrast image in the cases when image regions occupied by the dominant tissue can be identified from the statistics of the image.

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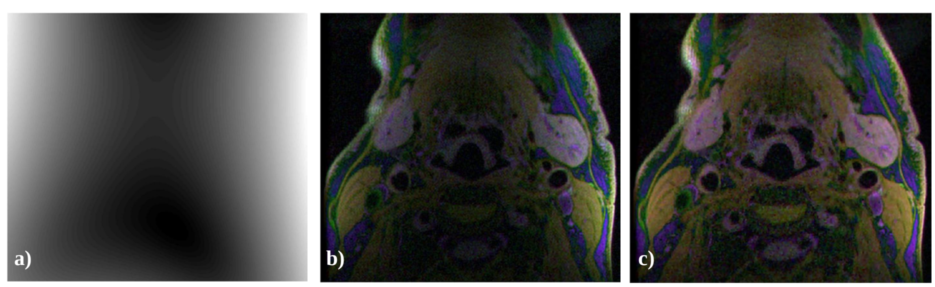

Figure 1. a) The SoS image of the individual sensitivities of the 4-channel carotid coil. R-G-B image from the triple contrast (M=3) carotid artery study. **b)** Original, **c)** intensity inhomogeneity corrected. (Red - PD, Green - T1, Blue - T2).

References

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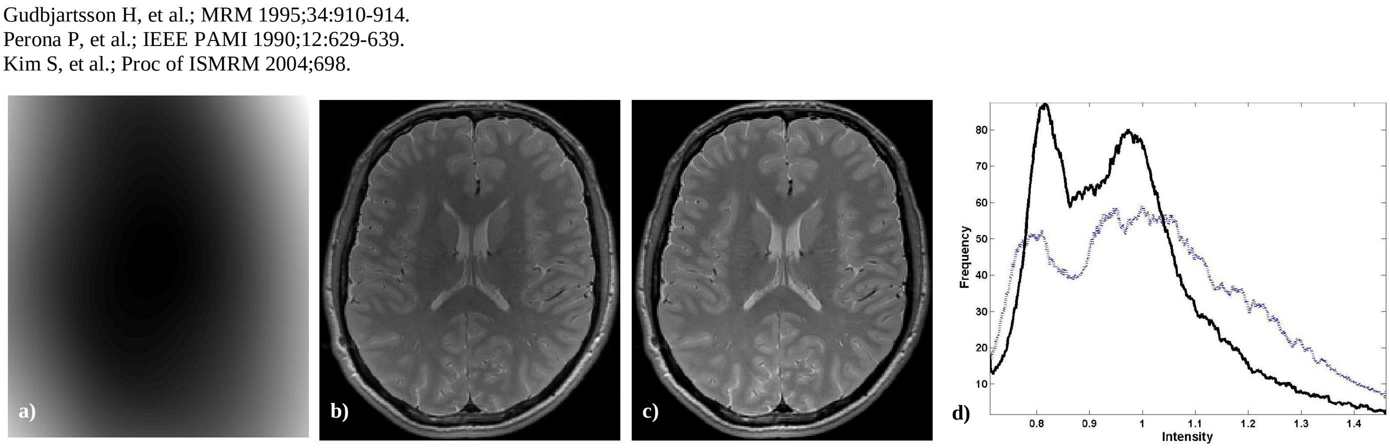

Figure 2. a) The logarithm of the SoS image of the individual sensitivities of the 8-channel head coil. PD-weighted image of the brain: **b)** original, **c)** intensity inhomogeneity corrected. **d)** Histograms of the original (dotted line) and the corrected (solid line) images.