Inhomogeneity correction at 7 Tesla using masked mean filtering of fast and low resolution gradient echo reference data

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Introduction

For exact anatomical assignment of activation from functional imaging studies, the high resolution and high contrast T1 images are frequently used. This structural information is obtained from the segmentation of 3D gradient echo data (e.g. MPRAGE). However, images acquired at high field strength of 7 Tesla suffer from severe B1 inhomogeneity resulting in erroneous or even failing image segmentation. In this study fast and low resolution gradient echo reference data with minimal intrinsic contrast are used to estimate the B1 inhomogeneity by masked mean filtering and correspondingly correct the MPRAGE intensity variation.

Method

All experiments were performed on a Siemens MAGNETOM 7 T scanner using an 8 channel Tx/Rx coil array. MPRAGE images were acquired with the following parameter 256x256x176, 1 mm isotropic resolution, TR/TE/TI = 2200/3.89/1050 ms, acceleration 2. Low resolution low flip angle (1°) 3D gradient echo images were also acquired at the same location (64x64x44, 4 mm isotropic resolution, TR/TE = 7/3.42 ms). The parameters were selected to quickly acquire an image with very little contrast.

To correct the high resolution data a modification of the Masked Mean Filtering Correction (MMFC) is used [1]. First a binary mask is created from the gradient echo data by the application of a threshold. The bias field is simply calculated using a mean filter of kernel size k only considering the voxels in the foreground mask. The bias field is normalized to a mean intensity of one and the background pixels outside the mask are set to one. After appropriate interpolation to match the size of the high resolution MPRAGE, the data are divided by the bias field. All operations are performed in IDL 6.1.1 (ITT Visual Information Solutions, http://www.ittvis.com). The data sets were segmented using SPM5.

Result and Discussion

MPRAGE images before and after intensity correction are shown in Figure 1. For this position of the subject, the uncorrected image (Fig. 1A) shows high intensities in the hippocampus region that drop off rapidly in the superior and inferior part of the brain. This strong intensity variation is mostly removed in the corrected image (Fig. 1B). Brain segmentation (Fig. 2) results demonstrate that segmentation of gray and white matter is improved in the corrected image. This is particularly visible in the regions where signal intensity in the uncorrected MPRAGE images is significantly reduced due to B1 inhomogeneity. Even in this very problematic area with severe signal loss, large parts of the white matter are recovered and, in addition, the segmented gray matter is more clearly resolved.

The approach is based on Homomorphic Unsharp Masking (HUM) [1, 2], which performes the thresholding and filtering on the inhomogeneous data themself. HUM is a fast and effective way for the correction of inhomogeneities. However, the bias calculated from the image to be corrected is usually not completely independent from the image itself. Especially for high contrast images such as MPRAGE with generally lower intensity in the cortical structures, the correction field tends to overcompensate the data. Here our approach extends the principle by the adition of a fast acquisition of a image data set with very little contrast but similar B1-sensitivity. For the correction of other sequences such as spin echoes, the corresponding relation in B1-sensitivity can be taken into account.

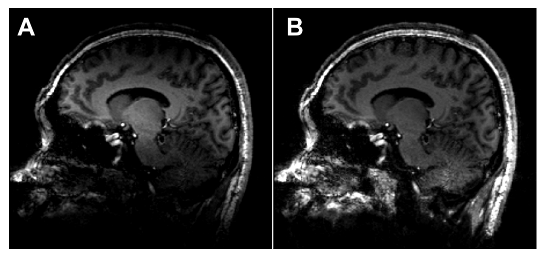

Figure 1: MPRAGE images before (A) and after (B) intensity correction.

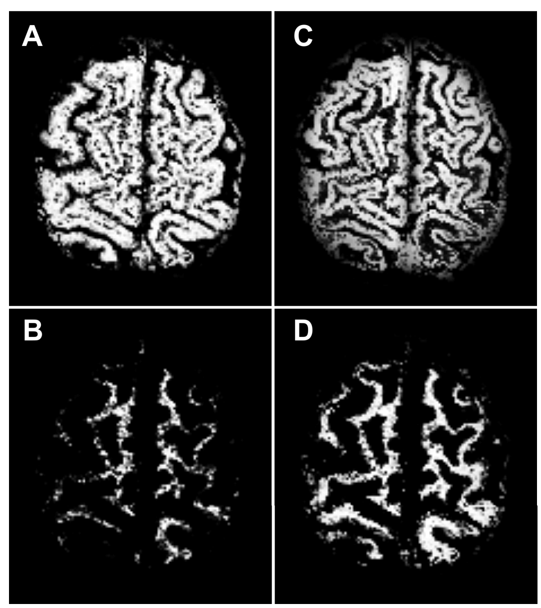

Figure 2: Segmented gray and white matter from uncorrected (A/B) and corrected (C/D) MPRAGE images in the upper parietal lobe. The corrected images give much better cortical structural definition.

Conclusion

MRAGE images at 7 T can be corrected using correction field derived from a fast low-resolution, low flip angle, short TE 3D GRE data set. The overhead for intensity correction is minimal. Therefore, the method can be applied to 7 T studies to obtain robust segmentation of gray and white matter with good structural definition.

Reference

[1] Arnold JB et al. NeuroImage 13: 931-943 (2001)
[2] Harris GJ et al. Am J Neuroradiol 15:225-30 (1994)
[3] Narayana PA et al. Magn Reson Med 33:396-400 (1995)