

# A retrospective, fully automated and fast method for intensity inhomogeneity correction in 7T MRI

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**Target audience:** 7T MR Users; UHF Researchers and Clinicians

**Purpose:** Ultra high field (UHF) MRI offers a better image contrast and higher SNR enabling high-quality in vivo anatomical imaging with isotropic sub-millimeter resolution. However, the image homogeneity is affected by bias fields, such as the receiver coil sensitivities. Without correction, the acquired data cannot be used for tissue segmentation or classification. We propose a novel, fast and a fully automated image inhomogeneity correction method optimized for UHF applications without the need to acquire any additional reference data. We show preliminary qualitative comparisons between the proposed and a state-of-the-art method N4 [1] on data obtained at 7T.

**Methods:** The proposed method is based on the work of [2] and [3], using image entropy to assess image inhomogeneity. In contrast to former methods, we employ a bounded Nelder-Mead simplex optimizer [4] to minimize the Shannon entropy of the normalized joint intensity-gradient histogram. Image gradients are found by convolution with a Scharr-Operator [5]. We model the bias field as a low resolution image (5x5 “kernel matrix”) and interpolate to the high resolution using cubic b-splines. The coefficients of the kernel matrix are direct inputs into the optimizer. The current implementation determines the 2D bias field and later regularizes slices in 3D. The key preprocessing steps in our pipeline are:

- Subsampling of the image volume (~100x100x40 pixel);
- Background removal with Otsu thresholding [6];
- Robust histogram calculation initialization.

Data was obtained on a 7T whole body MR scanner (MAGNETOM 7T, Siemens Healthcare, Erlangen, Germany) using a 24ch head coil and 3D FLASH-sequence.

**Results:** Especially posterior, uncorrected slices show hyperintense signal (see Fig. 2 top row). Representative bias field correction results are shown in Fig.2, Part 2 (N4) and 3 (our method), while the approximated bias field using our approach is shown in Part 4. The proposed method shows superior performance in removing intensity inhomogeneities at 7T in the basal region of the brain, compared to N4 (see Figure 2, Part 3). On average, 130 sec are needed to process one 7T dataset using our method compared to 419 sec using N4 (WindowsXP 32-bit, i5 4-core, 3.2GHz, 4GBRAM) (see Table 1).

7T image volumes with N-Slices <sup>1</sup> 3D FLASH-Sequence (0.4mm iso)	N4:ITK <sup>2</sup> [s]	Purposed Method [s]
N = 131, TE= 22.47ms	470	165
N = 106, TE= 22.47ms	218	110
N = 131, TE= 12.47ms	419	147
N = 106, TE= 12.47ms	184	96

Table 1: Processing times 1) N denotes number of slices. 2) Parameter settings for N4: 25mm spline resolution, subsampling factor 4; other parameter default

**Discussion/Conclusion:** The proposed method is well suited for UHF-MRI, as no a priori knowledge or reference data is needed (e.g. data obtained with a body coil for image normalization). We have shown that the proposed method clearly improves the image intensity homogeneity of UHF-MRI. Furthermore, compared to former methods such as N4, our method is faster and shows a better performance in terms of inhomogeneity correction.

**References:** [1] N.J.Tustison, *IEEE Trans Med Imaging* (2010),pp.1310-1320 [2] B. Likar, et. al, *IEEE Trans Med Imaging* (2001) pp. 1398-1410 [3] J. V. Manjón, et. al, *Med Image Anal.* (2007); 336-345 [4] J.Nelder, R. Mead, *Computer Journal*(1965),pp 308-313 [5] H. Scharr, Dissertation: Ruprecht-Karls Universität Heidelberg (2000) [6] N. Otsu, *IEEE Trans Syst Man Cybern* (1979),pp. 62-66

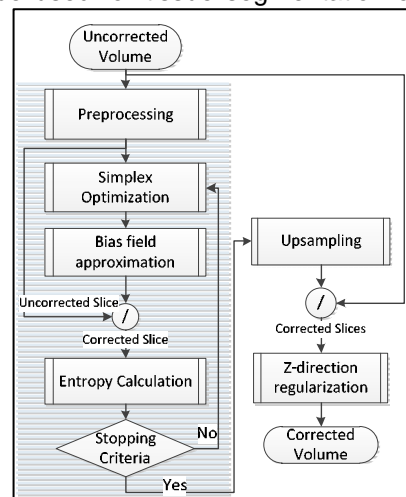


Figure 1: Depiction of the processing pipeline of the correction method

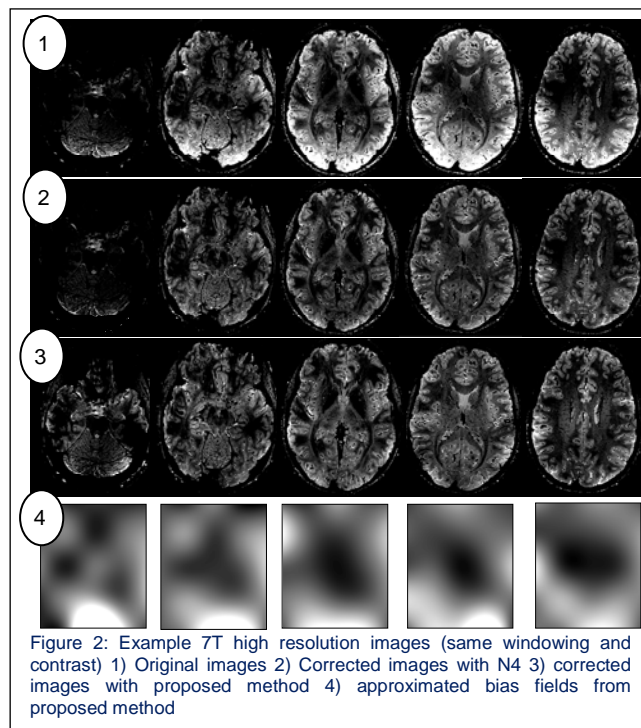


Figure 2: Example 7T high resolution images (same windowing and contrast) 1) Original images 2) Corrected images with N4 3) corrected images with proposed method 4) approximated bias fields from proposed method