Bias Field Correction of surface coil MR images of rodent brain acquired at high field

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Introduction Factors that affect signal intensity (SI) in magnetic resonance imaging include imperfections in the radiofrequency (RF) pulse profile, nonuniform flip angles caused by the transmit field and the electromagnetic properties of the object under study. The effects of these factors manifest as smoothly varying signal changes across tissue regions that should be uniform. This "bias field" affects the qualitative and quantitative analyses of MR images and becomes more pronounced at high field strengths. The aim of this study was to implement a bias field correction algorithm and use it to correct MR images of phantoms and adult rat brains acquired at 9.4T using a surface coil. The ability of this algorithm to correct signal intensity nonuniformities of MR images acquired at high field was evaluated.

Materials and Methods The bias field correction algorithm used in the present study was implemented according to the method described by Styner et al[1]. The bias field "corrupted" signal intensity can be modeled using the following equation: $I_{measured}(y) = I_{true}(y) \times \beta(y) + N(y)$ where I is the signal intensity, β the multiplicative bias field, N the noise and y the pixel position. Legendre polynomials were used to model the bias field in combination with a priori knowledge of the shape of the object to be corrected and estimation of tissue classes using a manually defined mask. Segmentation of rat brain images was based on a 3D atlas from [2]. The registration process was performed using the similarity 3D transform and the Thin Plate Spline transform after selection of several landmarks both on source (atlas) and a target images. Estimation of tissue class statistics used a nonlinear optimization evolutionary algorithm. Initial class values must be given to the algorithm for parameter recognition and were based on the histograms determined from manually drawn masks on images to be corrected. The adequate determination of the bias field and of the classes depends on the appropriate choice of Legendre polynomials degree, the number of iterations and the number of classes chosen. Fast Spin Echo (FSE) and single shot GRE-EPI MR images of a phantom and of an adult rat brain were acquired on an actively shielded 9.4T/31cm magnet (Magnex Scientific, Abington, UK) interfaced to a Varian INOVA console (Varian, Palo Alto, CA) equipped with 12-cm gradient coils(400mT/m, 120us). A quadrature transmit/receive surface RF coil with two geometrically decoupled 17 mm single-turn coils was used. First and second order shims were adjusted using FASTMAP[3].

Results and Discussion: The algorithm was tested using a simulated image consisting of vertical strips of two known classes 128 and 178 (Figure 1a). The image was corrupted with a multiplicative sinusoidal bias field with increasing strength (Figures 1b) and correction was applied using input class values=128, 178, degree of Legendre polynomials=3, number of iterations=2000. In the corrected images (Figure 1d), the bias field was efficiently compensated, showing the effectiveness of our correction algorithm. The distributions of pixels for the original (1e), corrupted (1f) and corrected (1g) images demonstrate that the bias field introduces a broad dispersion of pixel intensities across images. The correction enabled to partially redefine the two classes of intensities of the original image. In the homogeneous saline phantom (figure 2a, 2b) the bias field created a steep increase of pixel intensities across an image profile (Fig 2d). The coefficient of variation across a vertical profile dropped from 58% to only 5 % (Class Number=1, Polynomial degree=3, iterations=2000). The broad distribution of pixel intensities across the image was transformed into a narrow gaussian-like distribution of intensities demonstrating homogeneity throughout the whole image. The bias field correction algorithm showed similar improvement of *in-vivo* images of rat brain. After correction of low-contrast FSE images (Fig 3 a-d), (Class Nb=2, 3 degree polynomials, iterations=2000), the coefficient of variation across a vertical profile dropped from 32 to 10% and the intensity profile was constant compared to the original image profile (Fig 3d). Single shot GRE-EPI images needed the prior choice of 3 classes and 5 degree polynomials as well as 24000 iterations (Fig 3e) for adequate correction. The intensity distribution across the EPI images (Fig 3f) before correction was transformed into a narrow gaussian-like histogram demonstrating a significant reduction of the intensity variation across the image (fig 3g). In conclusion, application of a general-purpose algorithm to MR images of rat brain seems feasible with judicious choice of initialization parameters.

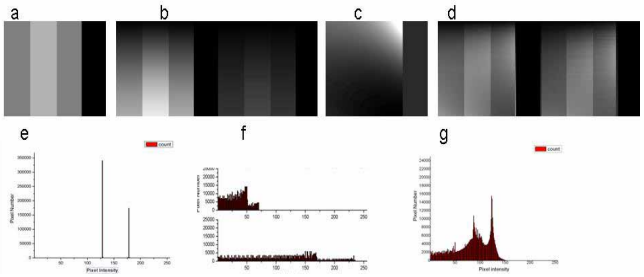

Fig1 (a) simulated image ;(b) corrupted images;(c) Bias field; (d) corrected images (e-f-g) Pixel intensity distributions of 1a-1b-1d

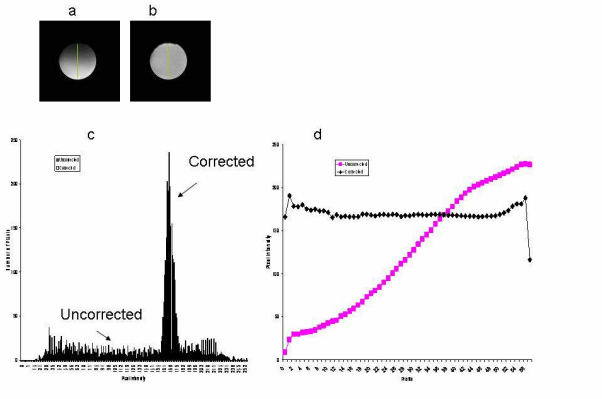

Fig 2 (a) Bias field corrupted Fast Spin Echo image (TR/TE= 4000/96ms; 16 echoes; ΔTE=12ms; slice thickness= 1 mm; 8 averages; FOV= 25x25mm; matrix=256x256) of a saline phantom.(b) Bias field corrected FSE image. (c) Overlaid histograms of uncorrected and corrected intensity distributions across the phantom images. (d). Comparison of intensity profiles across a vertical line drawn across the bias field uncorrected uncorrected image(Pink) and the bias field corrected image(black).

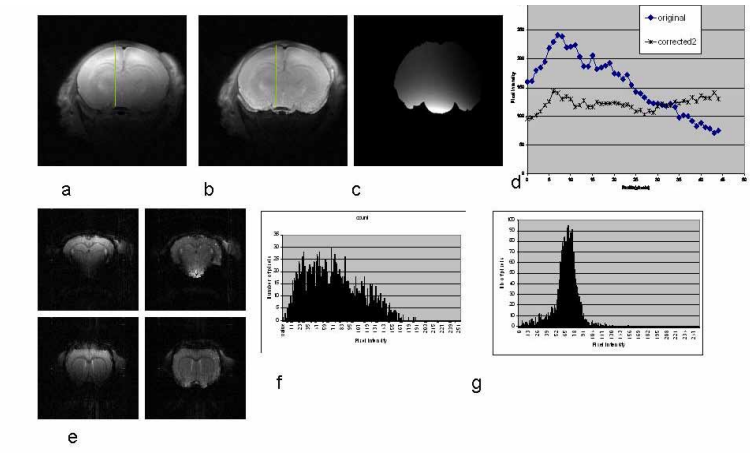

Fig3 :3a-d Fast Spin Echo images (TR/TE= 4000/96ms; 16 echoes; ΔTE=12ms; slice thickness= 1 mm; 8 averages; FOV= 25x25mm; matrix=256x256). (a). Prior bias field correction; (b) After bias field correction. (c): Bias field; (d):Intensity profiles across a vertical line drawn across FSE images (Blue: before bias field correction, Black after bias field correction). The bias field correction significantly flattened the profile of intensities across the image.**3e-g: 2 examples of single shot GRE-EPI images** ((TR/TE= 2000/29.85ms; slice thickness=0.5mm; SW=425KHz; FOV= 25x25mm; matrix=128x128). (3e):before (left) and after (right) bias field correction. (3f -3g): Intensity distributions before and after bias field correction.

Refernces: 1.Styner M et al, IEEE Transon Med.Img, 2000, 19, 153-165. 2.UCLA rat brains www./loni.ucla.edu/ 3. Gruetter R et al., Magn.Reson.Med 2000;43;319-323

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