Intensity Correction Using Image Extrapolation and Multi-Resolution Analysis

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Introduction: Compared to volume coils, surface coils enjoy higher SNR in the near area but suffer from image imhomogeneity due to the non-uniform sensitivity of the coils. There are many ways to correct the image non-uniformity. Retrospective methods use geometric or statistical analysis to separate the inhomogeneous field from the image itself. Low-pass filtering, expectation-maximization, fuzzy clustering, etc., are in the retrospective category. Recently, wavelets are applied to derive the bias field of the surface coil from the image. This approach decomposes the image into multi-level orthogonal subspaces with different resolutions. Assuming the coil sensitivity is slow varying, one can approximate the sensitivity profile by finding the optimal resolution level. This approach is essentially an optimized low-pass filtering method. One shortcoming of this low-pass filtering method is brightness of the boundary because of the sharp signal change at the boundary. Two methods proposed to remedy this problem have been replacing the noise with average signal of the non-noise image[1] (RA) and using maximum value projection (MVP)[2]. We propose a new method to reduce this boundary effect. Our approach is to extrapolate the image by taking the mirror reflection with respect to the anatomy boundary. Each pixel not within the anatomy will obtain a value from its mirror pixel in the image. This method gets rid of the sharp fall off of bias field due to absence of signal in the outer region. Although the extrapolation carries features of the image, only low frequency components are retained after we apply the wavelet analysis, and these low frequency components represent the varying sensitivity field.

Methods: The algorithm consists of four parts: 1. Find the boundary of the image; 2. Extrapolate the image; 3. Multi-resolution analysis; 4. Choose the corrected image with maximum entropy. For the first part, we first threshold out the noise using the method in [1], then find the boundary of the remaining part. Once we obtain the boundary, for each pixel not in the anatomy, there is one and only one pixel inside the boundary that is its mirror image with respect to the boundary. We then make these two pixels have the same intensity value. In step three, wavelet smoothing is applied to the new image and a multi-resolution analysis is performed so that images with different smoothing level are obtained. These images are candidates of the bias fields. The corrected image is obtained by dividing the original image by the smoothed images. The corrected image that has least entropy is regarded as the optimized one[3]. We used Daubechies's orthognal wavelet sets (D16) and no significant difference is shown for using other wavelet families. The numerical work is done in Matlab 6.5 with the help of wavelab toolbox provided by Department of Statistics of Stanford University. To test this method, we first acquired both phantom and brain images with a phased array coil (MRI Devices Corp., Waukesha, WI, USA), and then we obtain the non-uniform image by summing images from part of the channels. We also applied the RA and MVP approaches to the same images as a comparison. In the MVP, we took 10 iterations to get the smoothed field. In all methods, we found that in the multi-resolution analysis[2], level 4 to the phantom (128X128) and level 5 to the brain (256X256) gives best results.

Results: Figure 1 and 2 show the results of a phantom image and an image of human brain. The original inhomogeneous image is shown in a. b is the extrapolated image. c, d, e are the corrected image with RA, MVP and our method. As applied to the phantom, our method gives the best results. The extrapolated image is mostly smooth except near the boundary. This sharp discontinuity has little effect on the smoothing field because of its sole high frequency component. Therefore, the corrected image has minimal edge effect. RA works pretty well, edge blooming is surpressed. MVP, however, has some artifacts inside the image. This is because that the abrupt signal change near boundary brings some artifacts to the inside in each iteration of MVP. For the brain image, even though the image is very bright at the boundary, and many structure change near the boundary, our method works well. The contrast between gray matter and white matter is sharp and the image is more uniform. We can see that in the area that signals are smaller than average signal, the correction by RA was not good. This is because in that area RA over-compensated the signal loss. As of MVP, there is still artifacts near the center (brightness) as well as the boundary (darkness).

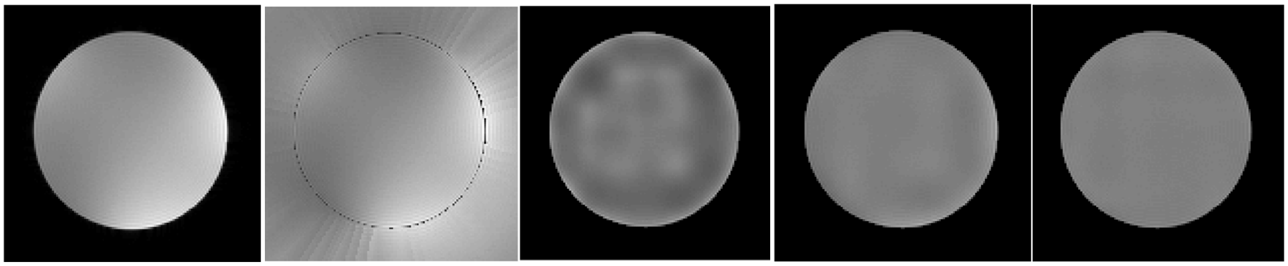
a b c d e

Figure 1. Phantom.

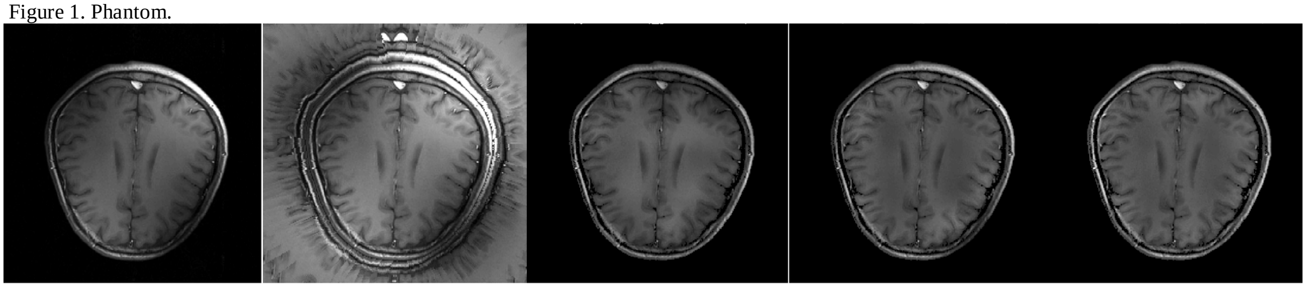
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Figure 2. Human brain.

Discussions: Our method shows promsing advantage over RA and MVP on the intensity correction of both phantom and brain images. It is fast and effective. Its power may get compromised if the image has complicated boundaries. The idea of extrapolating the image can be applied to any intensity correction method using low pass filter concept.

References:

1. M. S. Cohen, et al., Human Brain Mapping, 10:204-211 (2000).
2. F. Lin, et al, Human Brain Mapping, 19:96-111 (2003).
3. R. Guillemaud and M. Brady, IEEE Trans. Med. Imag., 16:238-251 (1997).