A nonparametric method for intensity non-uniformity correction in carotid MR Images

W. Liu[1], G. Wang[1], and H. Ding[1]

[1]Biomedical Engineering, Tsinghua University, Beijing, China, People's Republic of

Introduction: In recent years, high resolution MRI effectively assists the risk evaluation of carotid atherosclerotic disease on the findings of tissue compositions within carotid artery wall and their changes. Surface coils take an important role to acquire carotid MR images and improve the signal-noise ratio (SNR). But the inhomogeneous sensitivity of the coils may cause intensity non-uniformity of images. To correct the non-uniformity of images, researchers have developed many approaches[I II]. V. Manjo´n et al. proposed a nonparametric method based on the minimization of image entropy[III]. We adopt the framework of this method to correct the practical serial carotid MR images with improved calculation efficiency. Experimental results demonstrate the proposed method has good stability and efficiency for the serial carotid MR images and the algorithm is prior knowledge independent.

Methods:

(1) The non-uniformity image model of the bias corrupted data

$$C(x,y) = B(x,y) \times R(x,y) + N(x,y) \qquad (1)$$

Where at location x, C(x,y) is the intensity of the corrupted image, R(x,y) is the real emitted intensity, B(x,y) is the value of the bias field and which is supposed to be smooth, and N(x,y) is the noise.

According to this model, the task of non-uniformity correction is to automatically seek a suitable smooth bias field B to correct the corrupted image.

(2) The extended definition of image entropy

To estimate the bias field B, We use the extended definition of image entropy to construct the cost function of optimization. The extended image entropy considers the geometrical information in addition to the intensity distribution. Let Y be an image with M pixels and L1 grey levels, and let G be the associated image corresponding to the magnitude of the local gradient with L2 grey levels. The normalized intensity-gradient joint histogram and the entropy associated to the histogram are defined as:

$$p_{ij} = \sum_{i=1}^{M} \frac{\delta(Y_m - i)\delta(G_m - i)}{M} \quad \forall i \in L1 \;\; \forall j \in L2 \qquad H = \sum_{i=1}^{L1} \sum_{j=1}^{L2} p_{ij} \log p_{ij} \qquad (2)$$

Concrete Steps:
1. Low-pass filter.
2. Background removing.
3. Image reduction.
3. Initialize the coefficients.
4. Use the given coefficients to generate the bias field with the B-Spline.
5. Correct the image with the bias field and calculate the entropy of intensity gradient joint distribution of the corrected image.
6. Optimize the coefficients with the pattern search algorithm for the minimization of the entropy.

Figure 1. Concrete steps of the correction

(3) Optimization method

We select pattern search algorithm as the optimization method, which generate a sequence of iterates without using any information of the derivatives of the objective function. It only depends on function values. We use the GADS toolbox in Matlab to implement the method.

(4) Concrete Steps

With the methods mentioned above, we design and implement a progress procedure to correct the image, as Figure 1 shows.

Results: We use custom designed surface coil on a 3.0T Philips Intera Achieva MR scanner, with the image size of 512*512. To speed up the iterative progress, we resample the image size to 128*128. The experiments were conducted on Matlab R2008a environment on Hp workstation with a Intel Xeon 3GHz and 2G of RAM.

Figure 2 shows the original images and the corrected images of four kinds of sequences. (a) 3D TOF (thickness=1mm, matrix=512*512*48, running time: 25min); (b) PDW (c) T1W (d) T2W (thickness=2mm, matrix=512*512*20, running time=10~15min). With the results we can find that the dark part in the middle of the image has been corrected effectively, the intensity of the image is uniform. However, we can also find that the area near the skin is a little lighter in several images.

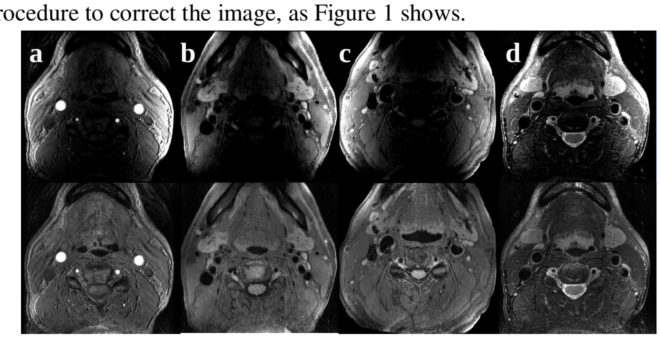

Figure 2. Correction results of the images of four kinds of sequences top row: the original images; bottom row: the corrected images.

Discussion and Conclusions: In the experiment, qualitatively, we have noticed that the levels of intensity and gradient (L1, L2 in equation 2) may have effect with the results of the correction. That is because the bias field is supposed to be smooth, to generate a good field means we should separate more levels in small value of gradient. So to find the influence of the weight of L2 quantitatively and optimize the selection is the farther work in our study.

In this study, we proposed an approach for the correction of the non-uniformity, which is caused by the inhomogeneous sensitivity of the surface coil. The approach is based on the minimization of the entropy associated to the intensity-gradient joint distribution. And the optimization algorithm is the pattern search method. The results show that the approach can correct the image effectively. Based on the good efficiency and the prior knowledge independence, this method can be widely used in the correction of the non-uniformity in MR images.

ACKNOWLEDGEMENT: This work is supported in part by the National Basic Research Program of China, under Grant 2006CB705700.

REFERENCE:

[I] Belaroussi, et al, “Intensity non-uniformity correction in MRI: Existing methods and their validation” Medical Image Analysis 10 (2006) 234–246

[II] Chao Han, et al, “A Multi-Scale Method for Automatic Correction of Intensity Non-Uniformity in MR Images” J Mag Res Imaging 13:428–436 (2001)

[III] V. Manjo´n, et al, “A nonparametric MRI inhomogeneity correction method” Medical Image Analysis 11 (2007) 336–345