# Improvement of Gradient-Reversal EPI Undistortion Method Using Local Pixel Adjustment

X. Liu[1], J. Zhong[2]

[1]Electrical and Computer Engineering, University of Rochester, Rochester, New York, United States, [2]Departments of Radiology and Biomedical Engineering, University of Rochester, Rochester, New York, United States

## Introduction

In MR imaging, the fidelity of image reconstruction relies on the homogeneity of the static magnetic field, which is not always achievable in many cases because of the imperfection of the magnet system or the susceptibility difference between different tissue. As a widely used fast MR imaging method in fMRI and DTI, Echo planar imaging (EPI) suffers more geometry and intensity distortions because of its inherently long acquisition window in phase encoding direction. The well-known fieldmap correction method [1] works well for most geometry correction but it performs poorly in intensity correction. Chang et. al. [2] proposed a gradient-reversal undistortion method which successfully corrects both the geometry and intensity distortion induced by field inhomogeneity. The essence of the method is to find the corresponding points in two EPI images of the same location but with the opposite phase encoding gradient directions. The general integral algorithm to find corresponding points does not work well in the case of high noise and with outlier points. Reinsberg et. al. [3] proposed an iterated optimal mapping method to find corresponding points in non-EPI image which however is inefficient for EPI image correction. We propose here an improved algorithm with local pixel adjustment to find corresponding points in EPI images with reversed phase encodes.

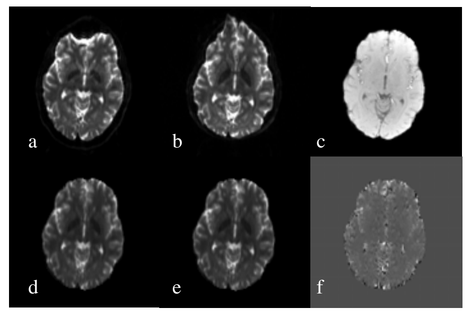


Figure 1. a) EPI with phase-encoding direction from A to P. b) EPI with phase-encoding direction from P to A. c) GRE anatomical image. d) Corrected image without local pixel adjustment. e) Corrected image with local pixel adjustment. f) Difference image of d) and e).

## Method

Two sets of axial brain images of volunteers were collected using SE EPI sequence on a Siemens 3T Trio scanner (Fig.1a and Fig.1b). The measurement parameters for the two sets of images are all the same except that one with phase-encoding direction from anterior to posterior and the other one from posterior to anterior. In-plane resolution is 128×128 and voxel size is 2mm×2mm×2mm. TE is 105ms. The images are resized by a factor of 3 using a bicubic interpolation method to increase the matching accuracy. For each x position along the horizontal direction, the initial corresponding pairs along the vertical direction are found using Chang's integral method based on equation (1), in which $y_1$, $y_2$ are corresponding pairs in the assumed noise-free data, $y_{01}$, $y_{02}$ are the edges and $I_1$, $I_2$ are the intensities in the corresponding images. The initial corresponding pairs are then broken into 16 fractions. In each fraction, the matching vectors are shifted in both directions for 1 to 5 pixels. The minimum sum of squared difference is calculated and the corresponding local adjustment is recorded and applied to the original corresponding pairs. From the corresponding pairs we can restore the undistorted coordinates and intensities from distorted images using equation (2) and equation (3), here $y_1$, $y_2$ and $I_1(y_1)$, $I_2(y_2)$ are coordinates and intensities of the corresponding pairs. Gaussian smoothing is applied to the voxel displacement map based on the fact that the field inhomogeneity is mostly low frequency. The algorithm was applied in the either edge of the brain along the phase encoding direction. The results were averaged to increase SNR.

$$\int_{y_{01}}^{y_1} I_1(y)\,dy = \int_{y_{02}}^{y_2} I_2(y)\,dy \qquad (1)$$

$$y = \frac{y_1 + y_2}{2} \qquad (2)$$

$$I(y) = \frac{2I_1(y_1)I_2(y_2)}{I_1(y_1) + I_2(y_2)} \qquad (3)$$

## Result and Discussion

Figure 2 shows the profile plots at the x position of 43 for the images in Fig 1. The integral method without local pixel adjustment (Fig 2b) matches the two profiles globally but there are some mis-registrated points, which result in the incorrect undistortion and blurring in the processed image. After the local pixel adjustment, the two profiles are matched more accurately (Fig 2c). The sum of squared difference in whole image was found to be 7.9e8 and 2.9e8 before and after applying the local adjustment. So the geometry and intensity can be corrected from the distorted image more accurately. Compared Fig. 1e) to Fig. 1d), one can observe a higher sharpness and more details in the locally corrected image. Also, from the difference image (Fig 1f) one can see the enhancement at edges in the locally corrected image. Using the integral method as an initial global matching function, we demonstrate that the local pixel adjustment algorithm proposed in this work can effectively improve the current phase-reversal method.

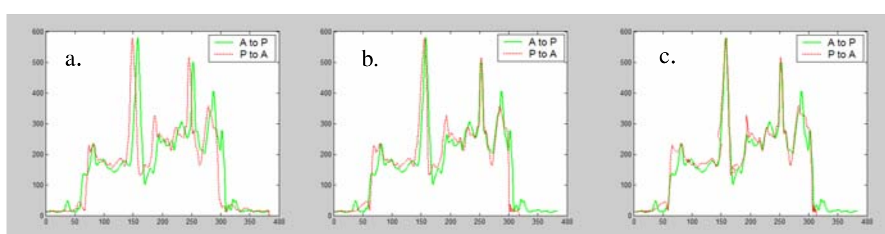


Figure 2. The profile plot at the x position of 43. a) Original plot before matching. b) Plot after global matching only. c) Plot after matching with local pixel adjustment.

## Reference

[1] P. Jezzard, et. al., MRM 34, 65-73 (1995) [2] H.Chang and J. Fitzpatrick, IEEE Trans Med. Imag.,11(3) , 319-329 (1992)
[3] S. Reinsberg, et. al., Phys. Med. Biol. 50, 2651-2661, (2005)