Using Genetic Algorithm (GA) to Improve Gradient-Reversal Method for Susceptibility Distortion Correction

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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 tissues. 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. Distortions are predominantly in the phase encoding direction and they are worsened at higher magnetic fields. 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 [3]. We propose here to use Genetic Algorithm (GA) to improve the performance of matching of corresponding points. An example of combination of this algorithm and a new pulse sequence to achieve further improved susceptibility corrections will be given in a separate abstract.

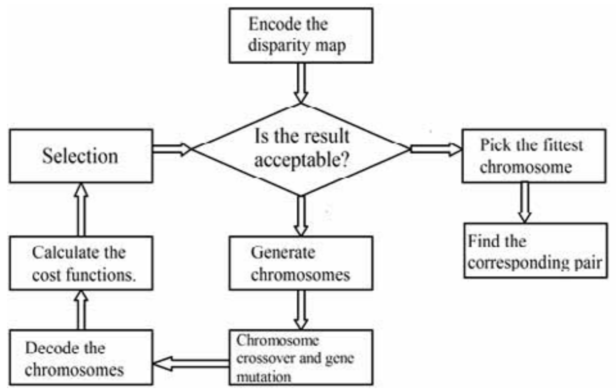

Fig 1. The flow chart of GA implementation in searching corresponding pair in an image for two acquisitions with reversed phase-encode gradient trajectories.

Methods

GA is an optimization search method using stochastic global searching approach that is inspired by natural biological evolution [4]. GA uses the concepts of individuals, mating, chromosome crossover, gene mutation, fitness, and natural selection. It is an iterative procedure that keeps a population of candidate solutions in forms of chromosomes. Each generation of the chromosomes are generated from last generation using chromosome crossover and gene mutation. At the beginning, the initial gene pool is filled with randomly or intentionally generated gene, then these chromosomes are evaluated using problem dependent fitness function. After the natural selection, the survived chromosomes will be used to generate next generation. The iterative procedure stopped once an acceptable solution is found. The flow chart of GA is shown in Fig 1.

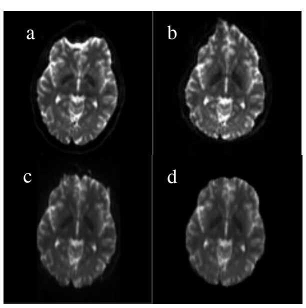

Fig 2. a) EPI image with phase encoding from A to P. b) EPI image with phase encoding from P to A. c) Corrected image using regular GR method. d) Corrected image using GA improved GR method.

Two sets of axial brain images of volunteers were collected using SE EPI sequence on a Siemens 3T Trio scanner (Fig.2a and Fig.2b). 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. The initial corresponding pairs are then broken into 16 fractions. In each fraction, the GA method is used to find the corresponding pairs. The sum square difference between the two corresponding lines used as fitness function. The stop condition is set to when the maximum 100 generations are reached.

Result and Discussion

Fig 3 shows the line profile before and after matching. Most the features of the profiles of the two lines are matched quite well. One can observe there are still unmatched parts in GA matching. That is probably because the generation number is not large enough for them to converge completely. Fig. 2c and Fig. 2d show the correction result. GA improved GR method corrected the susceptibility artifacts in the front lobe successfully. Corrected image with GA algorithm displays more intensity and geometric fidelity. It should be pointed out that the GA method is very time consuming. Improvements are still needed for the algorithm optimization.

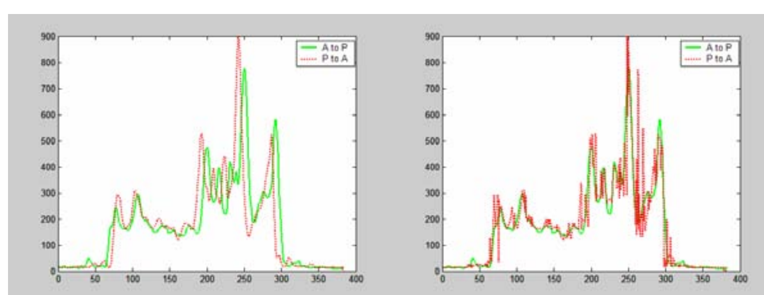

Fig 3. The line profile before and after matching can be matched.

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] X. Liu and J. Zhong, ISMRM 14th annual meeting, p.2340 (2006) [4] K. Han, Pattern Recognition. 34: 1729-1740 (2001)