Image-based estimation method for field inhomogeneity map in brain EPI image

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Target audience: Neuroradiologists and Researchers in image processing.

Purpose

Echo-planar imaging (EPI) suffers from geometric distortion due to magnetic field inhomogeneity. In order to correct for the image distortions, many methods have been proposed [1-3]. Most of these methods consist of two steps: estimating the map of the magnetic field distribution and then correcting for the image distortion based on the estimated field map. These methods require an additional acquisition for the field map. However, it is known that subject motion, respiration and other physiological noise between EPI acquisition and field map acquisition can lead to errors in the field map estimation, and the errors can lead to further distortion in the image in correction step [3]. In this study, our purpose was to develop a novel image-based method for estimating the magnetic field map using the distorted EPI image and T1 weighted image (T1WI) which requires no additional acquisitions for estimation of the field map.

Materials and Methods

Image-based estimation method for field map: Our basic idea for estimating the field map is to reproduce the distorted EPI image based on MR imaging physics. Our method synthesizes the distorted image to match the measured EPI image through the generating process of EPI image by changing the magnetic field. First, the T1WI was divided into head region and air region based on the intensity histogram, and then brain extraction and tissue segmentation were applied to head region by using FSL tool [4]. After that, an MR signal was simulated on a voxel-by-voxel basis based on the tissue in segmented T1WI and magnetic field map, and was stored in k-space according to conventional single shot spin echo EPI trajectory. The synthesized EPI image was reconstructed from the k-space by applying 2D inverse Fourier transform. We estimated the field map ΔB by minimizing of the least-square cost function using measured EPI image $Y(x,y)$ and synthesized EPI image $I(x,y,\Delta B)$. The minimization of the cost function was performed by iterative conjugate gradient algorithm. In our iterative method, the synthesized EPI image in current step was generated by using field map estimated in previous step. Our method was started with an initial field map of zeros, and then the estimated field map was updated by gradient decent of the cost function with respect to ΔB.

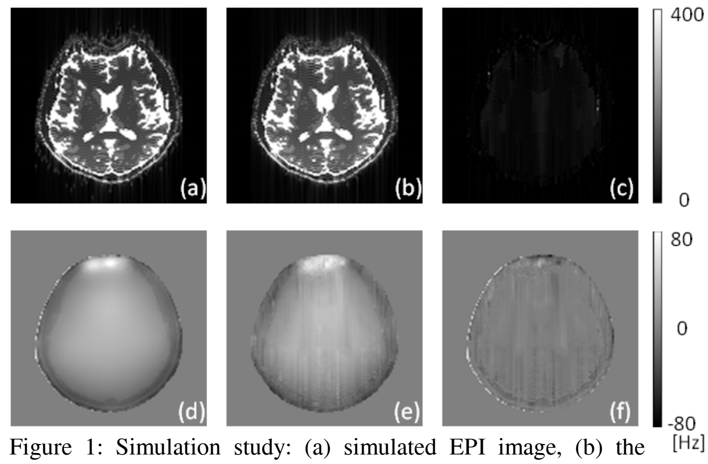

Figure 1: Simulation study: (a) simulated EPI image, (b) the estimated EPI image, and (c) absolute of difference image between them. (d) The ground truth map, (e) the estimated field inhomogeneity maps, and (f) the difference image between them.

Simulation study: In order to evaluate the performance of our proposed method, the simulated EPI image, distorted by a "known" magnetic field inhomogeneity map, was used for estimation of the field inhomogeneity. The magnetic field inhomogeneity map was computed based on the segmented real T1WI using susceptibility-voxel convolution (SVC) method [5], and this map was ground truth. The simulated EPI image was generated based on this field map and the real T1WI. T1WI of healthy volunteer was acquired using a 1.5-tesla clinical scanner (Magnetom Symphony, Siemens) with an 8-channel phased-array coil, and obtained using an MPRAGE (magnetization prepared rapid gradient echo) sequence (FOV: 230 mm, TR=2090 ms, TE = 3.93 ms, TI = 1100 ms, flip angle = 15 degrees, 256×256 in-plane resolution, 1 mm thickness).

Results and discussion

Figure 1(a), (b) and (c) show the simulated EPI image used in our simulation study, the estimated EPI image by our proposed method, and absolute of difference image between them, respectively. The value of the normalized root mean square error (NRMSE) between the input EPI image and the estimated EPI image was 0.072. Figure 1(d), (e) and (f) show the field inhomogeneity maps computed by SVC method, i.e., ground truth, the estimated field inhomogeneity maps, and the difference images between them. The NRMSE in Hz between the estimated field map and the true field map was 0.357. The estimated EPI image and field map by our method were in good agreement with the simulated EPI image and the ground truth, respectively. The simulation experiment suggests that the field map can be estimated using both of distorted EPI and T1WI.

Conclusions

We have developed an image-based estimation method for the magnetic field map based on the distorted EPI image and T1WI of brain. Our preliminary results demonstrate that the magnetic field inhomogeneity in EPI image can be estimated by our method without any additional acquisitions for estimation of the field map.

References

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