Geometric and Intensity EPI Distortion Correction for 7T fMRI Using Simultaneous Classification and Registration

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Introduction:

Echo planar imaging (EPI) is a rapid imaging sequence widely used for fMRI acquisitions. However, it is prone to geometrical distortions, especially at ultra high-field. Deformable image registration is used to correct the distortions by registering EPI image to an undistorted structural image. However, within the field of view of the object, any change in geometry can redistribute the acquired signal over the reconstructed voxels (Fig. 1). Such intensity changes often cause matching ambiguity during the registration process. To address this limitation and to tackle both geometric and intensity distortion at the same time, we propose to correct these distortions using simultaneous tissue classification and image registration.

Methods:

The geometrical distortion is corrected using the multi-modal diffeomorphic demons algorithm [1], which co-registers the distorted EPI image to a T1 image; the intensity distortion is separately estimated via tissue classification. Since the geometric and intensity distortions are correlated by the Jacobian of the deformation field, the estimated intensity distortion can provide a new Jacobian factor to refine the deformation field obtained from the non-rigid registration step.

Five volunteers were scanned on a 7T MR scanner (Siemens, Germany). A structural T1 image was acquired using the MP2RAGE [2] sequence and a resting-state fMRI run (matrixsize=160x160x64, TE=29ms, TR=5000ms) was acquired using a standard EPI sequence. The proposed simultaneous classification and registration (SCR) is compared with the multimodal diffeomorphic demons (MDD).

Results:

From visual assessment, the SCR registration results show clear advantages over the MDD method for all five cases (Fig. 2). The registration accuracy was also improved quantitatively, as validated by measuring the brain shape recovery ratio (DICE) (Fig. 3(a)), and the geometric distance error computed from 10 manually-defined landmarks located in regions with large distortions (Fig. 3(b), $p=0.01$).

Discussion:

The results demonstrate that the proposed method achieves better distortion correction compared to a standard registration algorithm. Due to the high signal sensitivity of 7T scanner, the classification of EPI image on which the proposed method highly depends is generally better than that of a comparable 3T image. Moreover, the bias field, although stronger than at 3T, is also easier to correct. Future work will be addressed to validations in a realistic task-fMRI study.

[1] Lu et al., ISBI 2010. [2] Marques et al., Neuroimage. 2010

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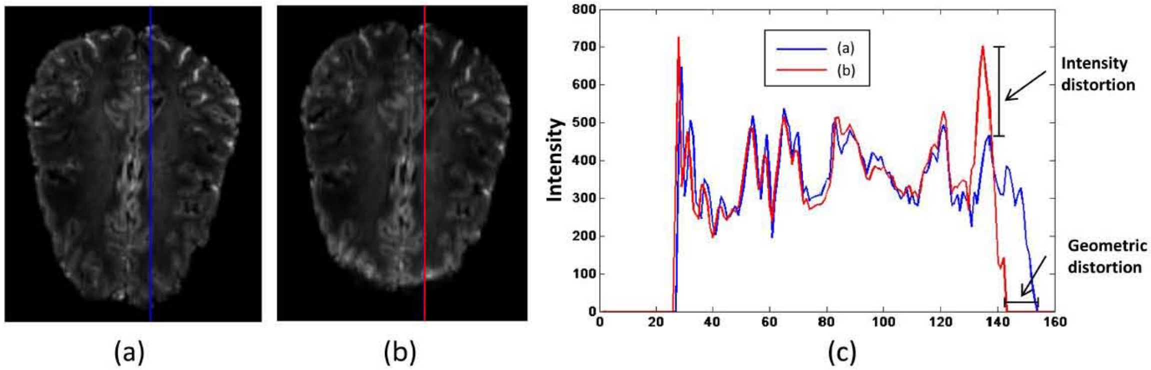

Fig. 1. (a) Distorted 7T EPI image, (b) Corrected EPI image of (a), (c) Intensity profile along the line from top to bottom in (a) and (b). Geometric distortion more than a centimeter occurs in the frontal lobe, causing signal intensity attenuation.

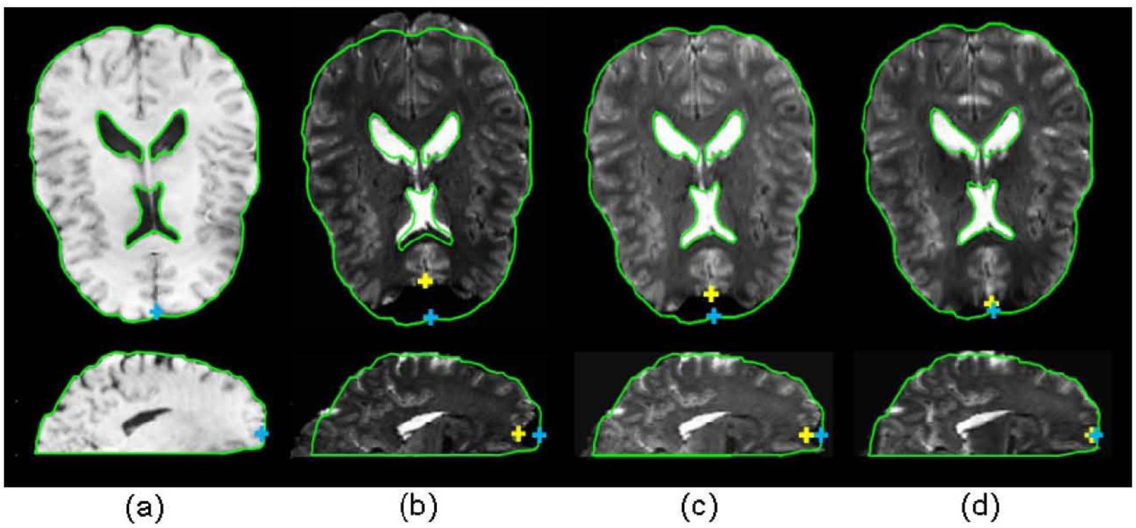

Fig. 2. Correction results from different methods on case 2, (a) T1 image, (b) distorted EPI image, recovered images by (c) MDD, (d) Proposed SCR method. Green line is the contour of reference brain overlaid on each result. Blue cross represents one manually-defined landmark in the T1 reference and yellow cross is the corresponding landmark in the EPI images.

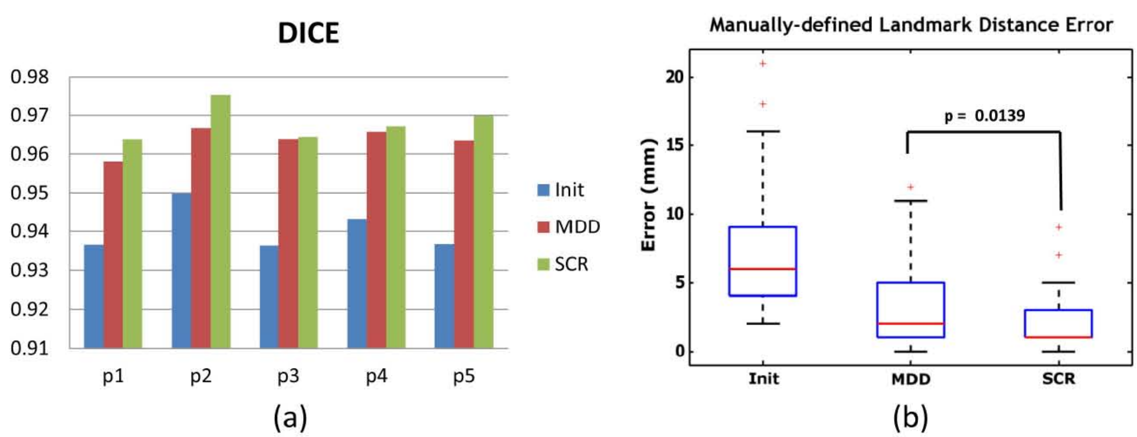

Fig. 3. (a) DICE coefficient between the T1 structural images and the recovered images using the initial EPI, MDD and proposed SCR. (b) Manually-defined mean geometrical distance errors of registration results from MDD and SCR.