Assessment of accuracy in mapping-slice-to-volume for motion correction of fMRI time series

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Introduction

Subject head motion during fMRI data acquisition is a major source of localization error in fMRI studies. The effect of motion artifacts and subsequent impediment in accurate activation studies are difficult to determine since accurate measurements of head motion are not readily available. A motion correction scheme that accounts for interslice motion, in-plane or out-of-plane, by retrospectively mapping each EPI slice into a 3D reference anatomical volume, map-slice-to-volume (MSV), has been in use for fMRI data analyses [1,2]. MSV offers more effective motion correction compared to the generally used fMRI analysis methods employing volume alignment of EPI with the assumption that there is no motion between slice acquisitions. In practice, neighboring slices can be subject to different motion parameters. This study presents assessment of MSV accuracy in determining motion parameters and activation localization by using a simulated MRI data with known motion.

Methods

A mathematical phantom data were created to represent a simulated fMRI time series. Simulated T_1 and T_2–weighted MRI volumes were obtained from International Consortium of Brain Mapping (ICBM) [3]. Time series data were produced by rotating the ICBM's T_2–weighted MRI volume at randomly chosen angles in three directions, x, y and z to include in-plane and out-of-plane rotations, in the range of –9 to 9 degrees. The initial and final random orientations were selected at each three second interval, and then smoothed by a cubic spline fit to simulate smoothly varying head motion. The resulting smooth functions were interpolated (between the initial and final orientations) to obtain the orientation of each slice in the time series. Each slice was subject to a set of rotation angles and a simulated fMRI volume consisted of slices stacked in a interleaved acquisition fashion. The final image resolution was 1.56x1.56x6 mm in 128x128x14 matrix. Two time series data, one with no noise and for the second volume, 5% noise generated with Rayleigh function was added added to the original simulated T2-weighted MRI before the motion parameters were applied. For activation simulation, intensities of selected regions were incremented by 5%.

Motion correction: The 3D mapping of an initially displaced 2D slice image, synthesized using a simulated T2-weighted MRI volume from ICBM, with an anatomical volume, T1 weighted MRI from ICBM, uses a rigid body transformation and MI as a cost function [1]. In this study, the initial process of image warping for geometric distortion normally present in EPI slices was omitted since the motion simulation employed only rotation of head with no non-linear distortion term. The automatic rigid-body MSV registration, driven by the mutual information metric of gray values in an image pair, was performed to determine the spatial slice profile relative to the volumetric reference data at the time of acquisition. This was followed by MSV registration to map each warped EPI slice to the spatial location in the 3D SPGR reference data. Fig.1 shows a diagram of MSV process. The resulting rigid-body transform is used to determine the final position of each slice.

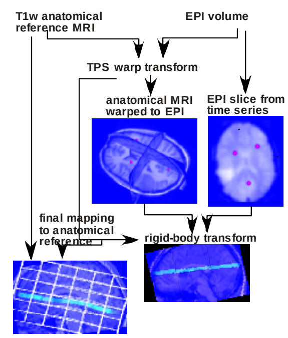
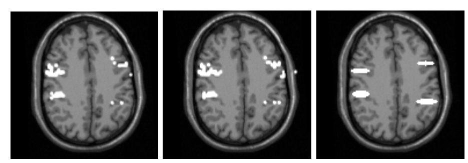


Fig.1.

Results

The rigid body transform vectors were computed throughout the time series data. The resulting motion parameters, specifically rotation angles, decomposed from the registration vectors were analyzed for both data sets, noiseless and 5% noised data. Error in mapping accuracy increased with the added noise, from 0.051 to 0.056 in rms error.

Images in Fig.2 shows statistical maps computed following the MSV motion correction, for (a) no noise and (b) 5% noise added and compared with the truth.



(a) noiseless (b) noise added (c) truth

Fig.2

Conclusions

The effect of head motion in EPI data is difficult to estimate particularly due to the lack of the truth in motion parameters and activation in the brain. This study provides an assessment of the motion correction capability and significance of the effective motion correction using the MSV approach with which position displacement of voxesl at each slice excitation can be corrected. Further study will require comparison of activation analyses with other widely used realignment techniques using the simulated data sets.

References

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3. International Consortium of Brain Mapping (ICBM), McGill University (www.bic.mni.mcgill.ca/brainweb/)

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