Head Movement Correction for MRI With a Single Camera

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Introduction

Motion artifacts continue to be a significant problem in MRI of human brain. Prospective motion correction based on external tracking systems has been proposed to ameliorate this issue. Stereo optical tracking systems have been shown to give good real-time motion correction with reasonable accuracy [1,2]. However, the calibration of these systems is very complicated and time consuming, as it requires a camera system calibration as well as a calibration between camera and MRI system using dedicated phantoms. We therefore propose an alternative motion correction method for MRI that does not require calibration and can work with just a single video camera.

Method

Rather than using phantom calibration scans our method uses training scans to estimate head position and link the camera image measurement to the MRI scanner coordinate system. During the training scan, the subject is asked to slowly move his head in the directions that are least restrained, including rotations in the axial and sagittal planes. A series of EPI (parameters: 64×48 voxels over 24×18 cm^2, 18 2mm slices with 2mm gap, TE 20ms, TR 1s) and camera images were acquired simultaneously. From the camera images, image feature points were extracted to serve as indicators of head position. From the EPI images, motion parameters in the MRI coordinate system (3 rotations and 3 translations) between each volume are calculated with 3D registration [3]. Since camera images were acquired simultaneously, each camera image in the training data thus corresponded to such a motion vector. In the actual scan, the newly captured camera image is compared with the training camera images to find the most similar ones. The average of the corresponding motion parameters of those training images served as the estimation of the current head position.

An MR compatible infrared camera (MRC Systems GmbH, Germany) was fixed on a holder right above and in front of the head coil (Fig 1). The distance from the camera to volunteer's face was around 10cm. Surrounding the camera lens, six infrared emitting diodes were used to illuminate the field of view. With this close a view the spatial resolution was about 200um, and sub-millimeter movements could be detected.

In principle, head motion could be estimated from facial features. However, to avoid confounds resulting from facial twitches, our initial proof-of-principle experiment used a dark 4×3 cm^2 paper with white triangles that was fixed on the forehead of the volunteer (Fig 2). Corners of the triangles were extracted and used as feature points during image analysis. The summation of distance between feature points from two images was used to judge the similarity.

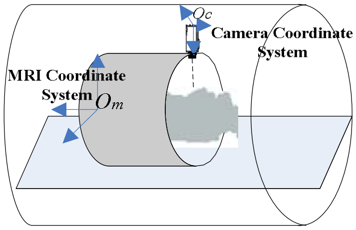

Figure 1: Experimental setup

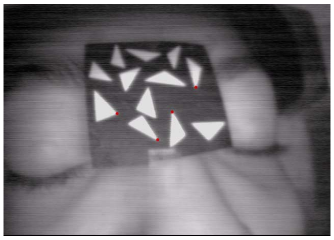

Figure 2: A camera image showing the patterned paper on volunteer's forehead.

Results

To estimate the accuracy of the method, 5 minutes of data were acquired, consisting of 300 EPI volumes and 300 camera images. The data were divided into a training set and a testing set. All the EPI images in the training set were registered to a reference (any one volume in the training set can be used as a reference) to get the motion parameters [3]. For every camera image in the testing set, the most similar images in the training set were determined based on the distance of feature points. The average motion parameters of these training images served as motion estimate for that test image, whereas the true motion was derived by registration of the test EPI image to the reference.

A *k*-fold cross-validation method [4] was used to evaluate the estimation error, where *k* was chosen equal to 10. For each trial 30 images where selected for the testing set, while the remaining 270 formed the training set. This was repeated 10 times for different test sets. Then the average error (difference between camera derived position and EPI registration parameters) across the ten trials was computed. Since the result of cross-validation is a random number that depends on the division of samples into subsets, to get more accurate error estimation, the 10-fold cross-validation was repeated 100 times using different selections of the subsets. The mean of the associated 100 errors were calculated. Fig 3 shows the resulting average errors as function of the number of images from the training set used to estimate the motion. We can see from Fig 3 that largest errors come from translation in the y direction and rotation about the z axis. This because in our setup, the camera is approximately facing the MRI system's y axis, resulting in a lower sensitivity in y compared to the other two.

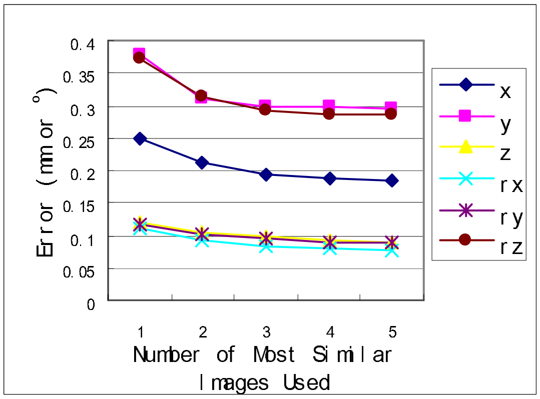

Figure 3: Estimation error.
x/y/z are translation errors, rx/ry/rz are rotation errors.

Conclusion

We propose a new motion correction method for MRI using single camera without any calibration. A short training scan is required to allow object motion estimation from the camera images. Initial testing results show an overall accuracy better than 0.3 mm translation and 0.3° rotation. We are currently adapting our method to allow motion estimation directly from facial features.

References

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