Sub-pixel image registration using ferrite-containing micro-beads

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Introduction

Cellular MR imaging has been tried for in vivo cell tracking in the living body even though low SNR and low spatial resolution of MRI limit practical applications [1,2]. For the longitudinal observation of cell movements in the living body, sub-pixel image registration with noisy MR images are essential since the cell size is far less than the image voxel size. In this paper, we propose a new sub-pixel registration method for the longitudinal cellular MRI. We used ferrite-containing micro-beads as micro markers inside the subject and registered the images using the information about the peculiar field inhomogeneity patterns induced by the micro-beads.

Methods

The ferrite-containing micro-beads induce strong local field inhomogeneity around them. Even though the micro-beads are smaller than the image voxel size, the local field inhomogeneity effects could extend over several nearby pixels. The field inhomogeneity pattern depends on the amount and shape of the ferrites inside the micro-bead. However, the overall shape of the field inhomogeneity resembles that of the equivalent magnetic dipole. Since the field inhomogeneity is static, i.e., time-invariant over the scan time, the field inhomogeneity pattern can be used as a marker in the image registration. We calculate the position of the micro-bead by computing the center of mass of the field inhomogeneity pattern and use them in the image registration. First, we identify the micro-bead residing area manually, and define the region of interest composed of 20x20x20 voxels. The center of mass is, then, calculated by integrating the image intensities along the x, y, and z axis in the region of interest.

We made cylindrical phantoms with 4% gelatin and 0.5% photoflo200 (Kodak, USA) to evaluate the accuracy of the image registration. We deliberately placed ferrite-containing polystyrene micro-beads (Bead & Micro, Korea), the diameter of 20μm to 150μm, at the central plane of the phantom. Figure 1 shows an optical microscope image of micro-beads containing plane. The phantom has been imaged with the 3D spoiled gradient echo sequence using the 3.0 T MRI system. The repetition time was 300ms, the echo time 17ms, the field of views 50x50x6.4mm^3, and the matrix size was 256x256x32 with 200μm isotropic resolution. To mimic longitudinal scans, we scanned the phantom multiple times with slight translation and rotation of the phantom inside the scanner in between the scans.

Results

We calculated the micro-bead positions in the two 3D images taken separately. The 3D images containing the micro-beads are shown in figure 2. During the interim time between the two scans, we slightly rotated the phantom inside the RF coil. To evaluate the accuracy of the position measurement, we calculated the distances among the micro-beads and compared them between the two 3D images (left-hand side in figure 2). The maximum distance error was found to be less than 50μm, which implies that the image registration can be made with 1/4 pixel resolution. With the measured micro-bead positions, we calculated the amounts of translation and rotation to be applied to the affine transformation for the image registration.

Discussions and Conclusions

The micro-beads make appreciable field patterns over several pixels around them. The peak error in estimating the micro-bead positions from the images of 200μm isotropic resolution was less than the 1/4 pixel size. Since micro-beads provide high contrast and localized field patterns, we expect that the micro-beads may also act as markers in the living brain. The micro-beads are to be used in the stem cell tracking imaging in which longitudinal scans over several days are required.

References

[1] Bulte JWM, et al., *NMR Biomed*, 2004, 17:484-499
[2] Gareau PF, et al., *Magn Reson Med*, 2003, 49:968-971

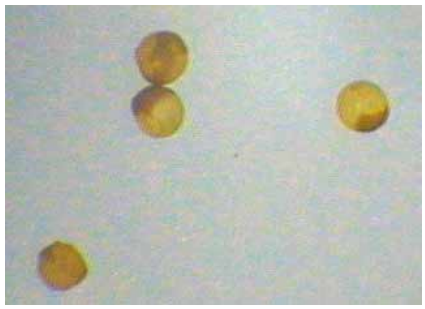

Figure 1. The ferrite-containing polystyrene micro-beads with the diameter of 20μm.

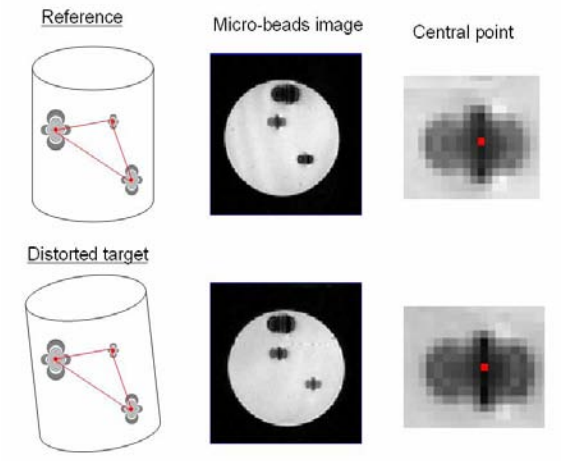

Figure 2. The reference image and the misaligned target image for the registration (schematic diagram, MR image, and the center of mass of the bead).