

A Robust MR-based Rigid-Body Motion Correction for Simultaneous MR-PET

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Introduction

With the integration of Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) into a hybrid system, simultaneous acquisition of the two modalities has become possible. Researchers now have the opportunity to investigate different aspects of biochemical processes with spatial and temporal coregistration. However, the long acquisition times of up to 60 minutes for PET can lead to motion artefacts. For the stand-alone PET in our Institute, this problem is addressed by using an external device to track head motion [1]. The measured motion data are then incorporated into the PET reconstruction process to correct the PET data for motion [2]. The use of an external tracking device is problematic in a hybrid MR-PET scanner, due to, for example, the confined space and the magnetic field. However, the MRI scanner is an ideal tool for delivering motion data during hybrid MR-PET measurements. In functional MRI studies, EPI time-series data are routinely used to correct for motion. In a hybrid MR-PET scanner this motion information can also be used to correct the PET images for motion, if the relative positions of the MR and PET scanners are known with sufficient accuracy.

Methods

All measurements were performed on a 3T MR-PET hybrid scanner, consisting of a 3 Tesla Magnetom Tim-Trio MR scanner and a BrainPET insert (Siemens Healthcare, Erlangen). All PET data were recorded in listmode, i.e. all coincidence events were written subsequently in a file with additional timing and block counter information for retrospective time-frame definition. During PET image reconstruction the data were normalised for different crystal efficiencies and corrected for scatter and attenuation. The reconstruction was performed with an implementation of the OP-OSEM (Ordinary Poisson – Ordered Subset Expectation Maximisation) algorithm [4] and calibrated in order to obtain quantitative Images in kBq/ml. To apply the MR-based motion information to the PET images, the relative position offset between the MR scanner and the BrainPET insert has to be known. This calibration was performed with a phantom measurement by simultaneously acquiring an MP-RAGE (1 mm³ isotropic resolution, 256x256x192 matrix) and an ¹⁸F PET image (3 mm resolution in the transaxial centre, 256x256x153 matrix). From these data, the offset between MR and PET was extracted by means of mutual information co-registration [3]. This procedure has to be performed only once and not on a per subject basis, assuming the BrainPET insert is not removed from, and/or repositioned in the MR scanner. Following calibration, a simultaneous ¹⁸F Fluorodesoxyglucose (FDG) PET and EPI MRI *in vivo* measurement was performed on a single subject. During the 30-minute acquisition, the subject was instructed to move her head every 3 minutes. In order to limit the induced motions to a range observable in clinical practice, the subject was fixated with a tape across her forehead – as is routine practice in our Institute to limit head motion. Motion parameters were extracted from the EPI images (64x64 matrix, 3.7x3.7 mm² in plane res., 45 slices, 3 mm slice thickness, TR=2.2 s) with SPM [5]. The PET data were then split into 10 time-frames according to the motion data and PET images were reconstructed. For each time-frame two images were reconstructed: one uncorrected, and one with motion correction. For the uncorrected PET image the attenuation map of the first frame (reference frame) was used for the reconstruction of all subsequent frames. The images of the individual frames were then averaged, generating a single uncorrected image volume. For the motion correction reconstruction the MAF [2] method was applied. First, the attenuation map of the head was adapted to the actual patient position for each frame by applying the measured motion parameters to the attenuation map of the reference frame (Figure 1, second row) and merged with the non-moving attenuation map of the MR coil. Second, the single frames of the emission PET data – which are still affected by head motion – were reconstructed with the corresponding moved attenuation map, (Figure 1, third row), and then corrected for motion by applying the inverse of the measured motion to each single frame image (Figure 1, fourth row). Finally, the attenuation and motion corrected images were again averaged to a single image.

Results

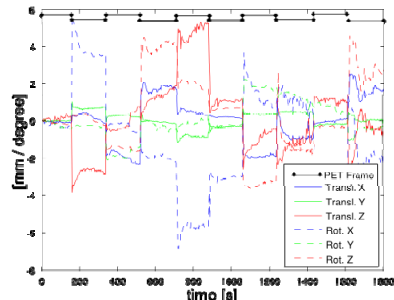


Figure 2: Motion parameters and PET frames.

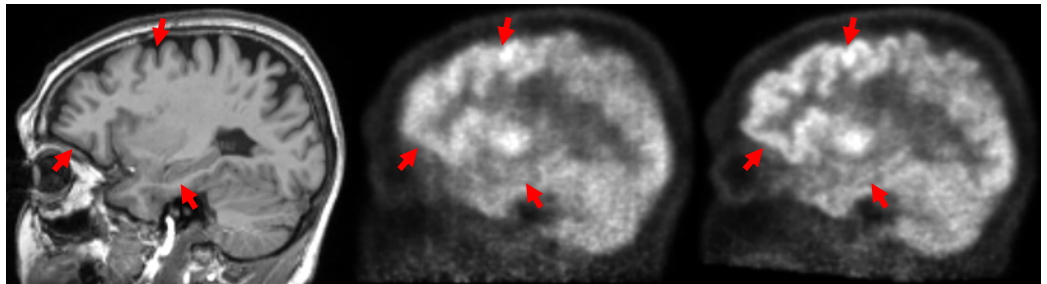


Figure 3: Normalised MP-RAGE image (left), PET image without motion correction (middle), and motion corrected PET image (right). The PET images were filtered with a 3D Gaussian kernel with FWHM 2 mm. A sharper delineation of the cortex is apparent in the motion corrected image.

Figure 2 depicts the measured motion parameters of the *in vivo* measurement and the corresponding PET frames. Figure 3 shows a single slice of reconstructed images, with a normalised MP-RAGE image as reference on the left, the uncorrected PET image in the middle, and the motion corrected PET image on the right. A clear resolution recovery is visible in the motion corrected PET image relative to the uncorrected image in the middle. The motion correction step adds an additional time penalty of 15 minutes to the standard reconstruction process which takes approximately 70 minutes.

Conclusion

Our preliminary results indicate that a frame based motion correction using EPI motion data and MAF [2] reconstruction leads to a visible increase in PET image quality with more anatomical structure visible in the PET image. Another MR-based motion correction approach presented in preliminary form [6] requires a calculation time on the order of a day. The method presented here on the other hand requires only minimal additional reconstruction overhead, making this method the first MR-based PET motion correction scheme available with processing times adequate in a clinical routine setting.

References

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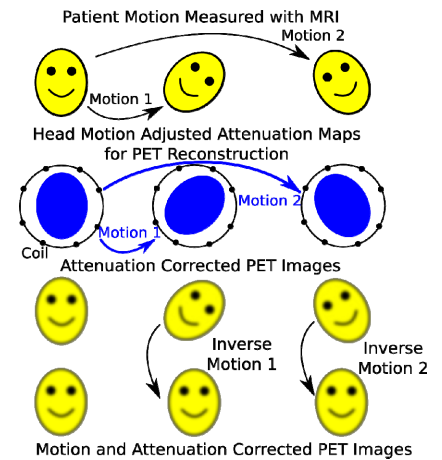


Figure 1: MAF reconstruction; the attenuation map of the reference frame is adapted to all following frames by applying the measured motion parameters, the attenuation corrected PET images are motion corrected by applying the inverse motion and averaged.