MR-assisted PET Motion Correction for Neurological Applications

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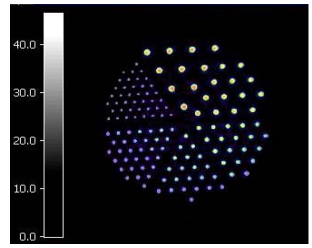

Fig. 1: Fused MR-PET images of a structured phantom (data acquired simultaneously)

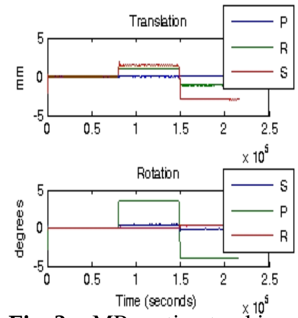

Fig. 2: MR motion tracking.

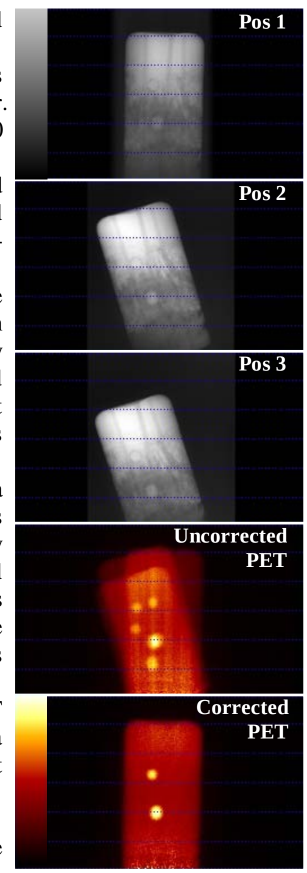

Fig. 3: MR-assisted PET data motion correction.

INTRODUCTION

Simultaneous MR-PET data acquisition [1-3] permits temporal correlation of the data, opening up opportunities impossible to realize using sequentially acquired data. One such example is using the MR information for motion correction (MC) of the PET data. Typically, subject motion is difficult to avoid and can lead to degradation (blurring) of PET images and to severe artifacts when motion has large amplitude. In the case of neurological applications efforts have been made to minimize these effects by using various techniques to restrain the head of the subject, but these methods have had limited success. Alternatively, methods to correct for head movements have been proposed. Image-based methods implement frame-by-frame correction but do not account for motion within the pre-defined frame. The most precise method applies MC on line of response (LOR) data and reconstruct them in listmode [4]. The motion tracking is provided by an optical tracker (e.g. VICRA/POLARIS), but the precision is limited by the residual freedom of the reflectors positioned on the subject's head. An elegant alternative presents itself in a combined MR-PET scanner, where the MR image is used to provide motion tracking. In this work, we demonstrate proof-of-principle for rigid-body MR-assisted PET MC. We propose a motion-triggered frame mode MC in LOR space, which allows us to take advantage of the high spatial resolution of the PET scanner.

MATERIALS AND METHODS

Motion correction is a twofold problem. First, motion has to be detected and characterized using the MR signal, and second, the correction algorithm for the PET data needs to be implemented.

Integrated MR-PET Scanner: An MR-compatible brain PET scanner prototype, recently installed at our site was used for our experiments. This system operates while inserted into the bore of the Siemens 3T TIM Trio MR scanner. The PET gantry is comprised of thirty-two detector cassettes, each consisting of 6 detector modules (about 28,000 crystals and 277 millions LORs).

MR-PET Data Spatial Co-registration: The spatial co-registration of the MR and PET data sets was first tested using a Derenzo phantom. This 20 cm diameter phantom with holes ranging from 2.5 to 6 mm in size was filled with 1.5 mCi of F-18 in water. PET data were acquired for 20 min and the images were reconstructed using the OP-OSEM 3D algorithm. Several MR sequences were run simultaneously with the PET data acquisition.

MR Motion Detection/Tracking: Rigid body motion is most easily tracked on the Siemens system using the standard 3D PACE method [5]. This requires that an EPI series be collected, and prospective real-time motion tracking is performed by registering each volume with the first in the series. Motion estimates are obtained every time a complete volume is acquired, typically every 2 or 3 seconds. For 3D FLASH acquisitions, we use embedded cloverleaf navigators (CLNs) to obtain motion estimates every TR (typically 20 ms) [6]. This method requires that an initial map be collected, and this takes about 12 s. Both of these methods are suitable for tracking the translations and rotations of the head that moves as a single rigid body.

PET Motion Correction Algorithm: Coincidence event PET data are acquired simultaneously with the MR data and stored in list mode format. The motion is accounted for in the post-processing step by "moving" the coordinates of all crystals based on the transformation matrix obtained from the MR. However, rather than correcting every LOR for motion, we correct a frame for which minimal motion was detected. Data in LOR space are then rebinned into parallel projection space (sinograms) using nearest neighbor rebinning. Similarly, a time weighted sensitivity is obtained using the same motion information. The emission sinograms from all the motion-triggered frames are added (i.e. prompt, variance-reduced random and time weighted sensitivity). The motion corrected image is reconstructed from these data and the reference attenuation correction using the OP-OSEM 3D algorithm.

MR-assisted Motion Correction–Phantom Studies: For these proof-of-principle studies, a rigid MR-PET phantom with enough internal structure for good navigator performance was constructed. A plastic platform with a lever arm that can be manipulated from outside the magnet was used to move the phantom to three different positions/orientations while simultaneously acquiring PET and MR data.

RESULTS AND DISCUSSIONS

MR-PET Data Spatial Co-registration: A prerequisite for using MR to guide the PET motion correction is the spatial co-registration of the two datasets. Fused MR-PET images from the phantom experiment are shown in Fig. 1, demonstrating the perfect agreement of the MR and PET volumes.

MR Motion Tracking: All of the prototype motion correction sequences to correct for motion in the MR image generate a motion log in real-time. A typical log of the motion obtained from a CLN sequence is shown in Fig. 2. The translations along and the rotations about the three orthogonal axes are plotted as a function of time.

MR-assisted Motion Correction–Phantom Studies: The MR images acquired in the 3 positions are shown in Fig. 3 (top 3 images). The PET image obtained by adding the reconstructed images without applying the MC is shown in Fig. 3 (4^{th} image). The first frame was considered the reference frame and the MR provided the transformation parameters (3 translations, 3 rotations) for the two subsequent frames relative to the reference frame. The image obtained after applying the MC is also shown in the Fig. 3, demonstrating substantial improvement. As a next step, the method will be tested in human subjects.

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