Towards Lissajous navigator-based motion correction for MR-PET

M. G. Ullisch[1,2], T. Stöcker[1], K. Vahedipour[1], E. D. Pracht[1], L. Tellmann[1], H. Herzog[1], and N. J. Shah[1,3]

[1]Institute of Neuroscience and Medicine 4, Forschungszentrum Jülich GmbH, Jülich, Germany, [2]Department for Psychiatry and Psychotherapy, RWTH Aachen University, Aachen, Germany, [3]Faculty of Medicine, Department of Neurology, RWTH Aachen University, Aachen, Germany

Introduction

With the combination of Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) into a single combined system, a novel imaging modality has become available. Exciting new study designs investigating different aspects of the exact same biochemical process are finally possible thanks to simultaneous MRI and PET acquisition. Due to long acquisition times of up to hours, motion poses a significant problem for PET images. Previously this problem has been addressed in PET by using external devices which track the motion of a marker attached to the subject's head [1]. The recorded data are incorporated into the PET reconstruction process to correct the PET data for motion [2]. Due to the magnetic field and the confined space in the MR-PET scanner, the use of an external tracking device is not easily feasible. However, the MRI scanner is an ideal tool for delivering motion data with minimal overhead during combined MR-PET measurements. Three-dimensional navigators – short MR acquisitions optimised for rigid body motion detection – are a promising tool for motion detection and estimation in MRI [3-5]. A novel navigator trajectory, the Lissajous navigator, which delivers motion parameters with six degrees of freedom, has been developed. By acquiring Lissajous navigators during a simultaneous MRI and PET measurement, motion data are available which can be utilized to motion-correct the PET data.
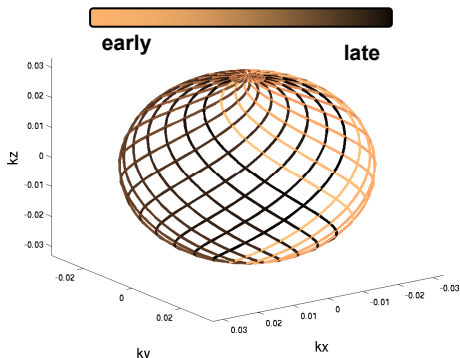
Methods

Figure 1: *k*-space trajectory of the Lissajous navigator

The Lissajous navigator covers a spherical surface in *k*-space with a Lissajous trajectory projected onto a sphere (see Figure 1). This trajectory has a moderate slewrate requirement compared to the spherical navigator allowing full coverage of the spherical surface without exceeding the hardware limit of the system. Rotational motion parameters were derived from the navigator by performing pattern matching on the magnitude data. Trial rotations were applied to the navigator and the squared difference between the rotated navigator and the reference navigator is minimised using a Nelder-Mead simplex method [5].

The Lissajous navigator acquisitions (8ms) were spliced into a FLASH sequence (TE = 5ms, TR=1500ms, matrix 64x40x32) acquiring a Lissajous navigator with a separate excitation pulse after each image line acquisition. To evaluate proper tracking of rotations, a two chamber cylindrical phantom [6] filled with a solution of 3.75g $NiSO_4$ x 6 H_2O + 5g NaCl per 1000g H_2O was measured on a 3 Tesla Siemens Magnetom Trio. Virtual rotations were introduced during the measurement by rotating the gradient pulses in a sinusoidal fashion around each of the principal axes while keeping the phantom constant. In order to minimize artefacts caused by the gradient rotations a TR of 1500ms was chosen.

Results

Figure 2 shows the rotational motion parameters extracted from the two-chamber phantom undergoing sinusoidal virtual motion with an amplitude of 30°. The applied virtual rotations are successfully tracked. The application of the Lissajous navigator is not limited to the FLASH sequence, as it is compatible with most relevant sequences for a combined MR-PET system. Figure 3 shows a combined MR-PET image of the two-chamber phantom with the inner chamber filled with demineralised water and the outer chamber filled with a 3.8g $NiSO_4$ x 6 H_2O + 5g NaCl per 1000g H_2O solution. The ratio of ^{18}F-radioactivity between the outer chamber and inner chamber is 4.5. The MR image is shown on the left with a grey scale, the PET image in colour on the right, and a combined MR-PET image in the middle.
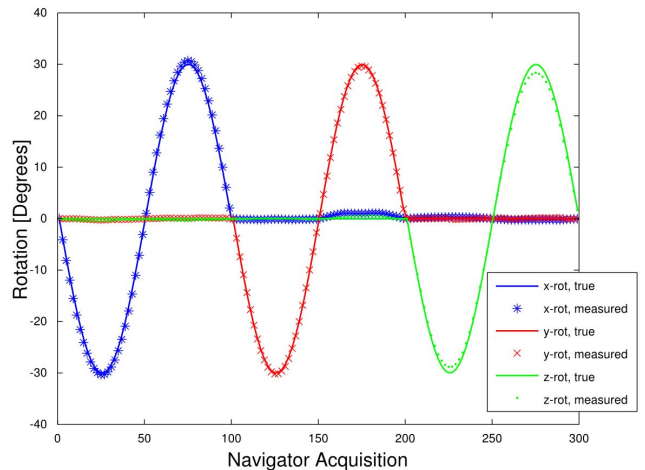

Figure 3: Combined MR-PET image of the two-chamber phantom. Acquired on a 3T Siemens Magnetom Trio with Brain PET insert.

Figure 2: Time course of measured and true MR virtual rotation parameters with Lissajous navigators spliced into a FLASH sequence

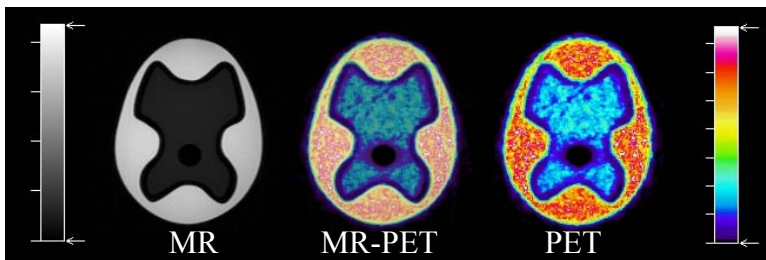## Discussion

The new navigator can be interleaved in most relevant sequences with minimal overhead causing a minor sequence-dependent increase in scan time. Our preliminary results indicate that navigator-based motion correction is a promising tool for rigid body motion tracking in a simultaneous MR-PET measurement. Knowing the MR-based motion data, the PET data can be corrected using the MAF [2] method.

References

1. Tellmann L, Fulton R, Pietrzyk U, Nickel I et al., Z Med Phys. 2006; 16:67-74 **2.** Fulton RR, Meikle SR, Eberl S, Pfeiffer J et al., IEEE Trans Nucl Sci 2002; 49(1):116-123 **3.** Welch EB, Manduca A, Grim RC, Ward HA, et al., Magn Reson Med. 2002; 47(1):32-41. **4.** Kouwe van der AJW, Benner T, Dale AM, Magn Reson Med. 2006; 56(5): 1019-1032 **5.** Ullisch MG, Stöcker T, Elliott MA, Vahedipour K et al., Proc. Intl. Soc. Mag. Reson. Med. 17 2009:4650 **6.** Lagarias, JC, Reeds, JA, Wright MH, Wright, PE. SIAM J Opt 1998; 9(1): 112-147 **7.** Herzog H, Tellmann L, Qaim SM, Spellerberg S et al., Appl. Radiat. Isot. 2002; 56:673-679