T1- and T2-Weighted MR Acquisition for Bulk Motion Correction for Simultaneous PET-MR

Christoph Kolbitsch[1], Claudia Prieto[1], Charalampos Tsoumpas[1], Christian Buerger[2], and Tobias Schaeffter[1]
[1]*Division of Imaging Sciences & Biomedical Engineering, King's College London, London, United Kingdom,* [2]*Department Digital Imaging, Philips Technologie GmbH, Innovative Technologies, Research Laboratories, Hamburg, Germany*

INTRODUCTION: Positron emission tomography (PET) is commonly used to detect and assess cancerous tissue. Recently, simultaneous PET-MR scanners have been introduced which provide metabolic information obtained with PET and high-resolution anatomical MR images [1,2]. PET data are usually acquired in multi-stations, where several 3D data sets are acquired at different bed positions. The time at each position can be used to obtain 3D MR data. However, patient motion during the long acquisition of 3D data in both imaging modalities poses a major challenge for PET-MR [3,4]. Bulk patient motion during the acquisition in particular can severely impair image quality.

To overcome this problem we present a novel image-based motion scout to automatically detect and estimate bulk motion from the acquired MRI which is then used to correct for motion in both PET and MR images. This is achieved by using a high-resolution Golden Radial Phase Encoding (GRPE, [5]) scheme. GRPE allows for the simultaneous reconstruction of 3D dynamics with different arbitrary temporal resolution from the same acquired data. First, the complete data are split into dynamic time frames, which are used to detect the time point(s) when motion occurred. Secondly, data are reconstructed before and after the movement for motion estimation. Finally, the estimated motion fields are used to correct for motion in the reconstructed MR and PET images. Our proposed approach was successfully assessed in healthy subjects for T1 weighted (T1w) gradient (GRE) and T2 weighted (T2w) spin (SE) echo images combined with PET simulations.

METHODS: GRPE trajectory: 3D data are acquired along radial lines in the 2D phase encoding (PE_1 – PE_2) plane (Fig 1a). Successive lines are tilted by the golden angle of 111.24° which leads to a homogeneous covering of k-space over time. This yields optimal distribution of radial PE lines for each dynamic image for any retrospectively selected temporal resolution.

MR image acquisition: A GRPE sampling scheme was implemented on a 3T MRI scanner (Philips Healthcare) for both GRE and SE sequences. In 3 volunteers T1w GRE (FA 10°, TR/TE 3.2/1.71ms, 2.7min) and T2w SE (FA 90°/120°, TR/TE 470/7.1ms, 13min) data were acquired using either a 32 or 6 channel cardiac phased array coil: 288mm^3 FOV, acquisition matrix: 192x192x144, 1.5mm^3 isotropic resolution. Respiratory navigation was employed in both sequences to minimise respiratory motion artefacts. During data acquisition volunteers were advised to carry out a bulk motion shift which led to sever motion artefacts (Fig 1b).

PET simulation: The PET simulation was carried out using segmented MR images with manually inserted virtual lesions [6]. The lesions had a diameter of 5mm and were placed at accurately determined anatomical landmarks.

Bulk motion detection: The acquired MR data was split into 24 dynamic time frames D_i (each with 30 radial PE lines) using a sliding window approach (window shift: 5 radial PE lines) (Fig 1c). All images were reconstructed using a non-Cartesian iterative SENSE reconstruction [7].

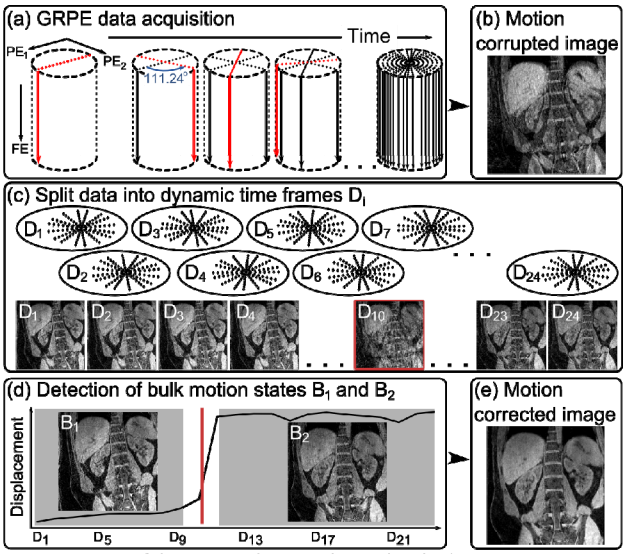

Fig 1: Overview of the proposed approach. For details please see METHODS.

The dynamics D_i are registered using a global affine registration algorithm [8] which yields information on the global displacement between different D_i (Fig 1d). Displacements larger than the spatial resolution of 1.5mm are detected as occurrences of bulk motion (red line in Fig 1d).

Bulk motion correction: A second set of images B_i was reconstructed describing each of the bulk motion states. These images were registered and transformed to the same motion state (i.e. motion corrected) using a hierarchical non-rigid registration [8]. The final 3D MR images are obtained by averaging the motion corrected images (Fig 1e). The obtained motion information was incorporated in the simulated PET reconstruction.

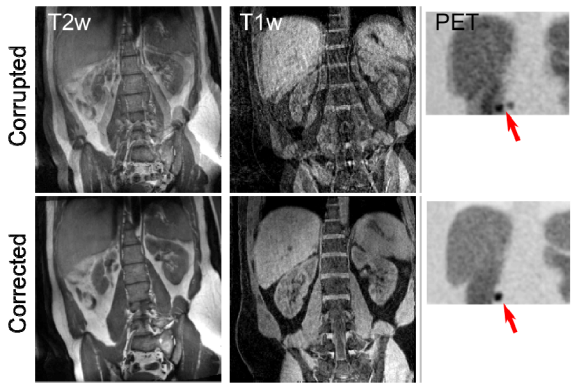

Fig 2: Results comparing the motion corrupted and corrected images for T2w SE, T1w GRE and PET simulations. Lesion indicated by arrow.

RESULTS: Bulk motion was successfully detected and corrected in all MR images. Representative motion corrupted and motion corrected MR and PET images are shown in Fig 2. Bulk motion artefacts and the improvements in image quality achieved with the bulk motion correction are clearly visible for both imaging modalities.

CONCLUSION: We have successfully demonstrated a technique which provides automatic image-based motion detection and correction for T1w and T2w 3D MR images with high isotropic resolution. In addition the obtained motion information can be used to motion correct PET images. Our approach does not require any additional data acquisition but utilises the obtained image data and can be applied to images with different contrasts. So far motion correction is carried out in image space. Future work will focus on integrating the motion correction directly into both the MR and PET reconstruction which could lead to further image quality improvements [9].

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