Flexible Inter- and Intra-scan Motion Tracking

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Purpose: MR examinations generally consist of several scans that are executed consecutively to image the same volume with different types of contrast. In case of motion of the target organ between consecutive scans, images of different contrasts may not be aligned anymore. Furthermore, some MR techniques such as fMRI, ASL, or DTI are based on data acquired several times from the same volume over a longer time period. In these cases, the data analysis can be corrupted, when the patient moves between consecutive acquisitions. While in-plane motion can be corrected to some extent retrospectively by image registration, through-plane motion yields data acquired from different locations which cannot be corrected for. In this work, we propose a flexible and generic method to detect and correct for both in-plane and through-plane motion between individual scans of an exam as well as between individual dynamic acquisitions of a scan. This ensures consistent scan geometry during the entire examination.

Methods: The technique is based on a fast "tracker" scan [1] similar to [2]: a set of three low resolution orthogonal slices are acquired to determine and track the position of the target volume. After the survey, which is used for planning the geometry of the diagnostic scans, a tracker is acquired which serves as a position reference for the entire exam. Then, before starting each scan of the exam or each dynamic of a scan, another tracker is acquired, which is registered to the slices of the reference tracker using a combination of rigid 2D registrations. The resulting 3D transformation matrix accounting for translation and rotation in all 3 directions is applied to correct the scan geometry and to acquire a new tracker in the new geometry. This process is repeated until the geometry updates between two consecutive tracker scans are below a certain threshold, in which case it is assumed that the original scan geometry is reached. Finally, the geometric transformation between reference and current position is applied to correct the scan geometry of the diagnostic scan or of the subsequent dynamics without any user interaction.

To interleave the tracker scan and the diagnostic scan at arbitrary time points during scan progression, a new method framework was developed [3]: multiple sequence descriptions are stored on the data acquisition system in parallel tasks, allowing a very fast switching between the different data acquisitions at predefined switch points. Therefore, the tracker scan can be planned with the full flexibility the scanner offers. After acquisition of the preparation measurements of both the tracker and the diagnostic scan, the data acquisition system can switch between the two sequences either once at the acquisition start or before each dynamic. With this framework, motion correction can be performed almost without any latency between the acquisition of the tracker and of the diagnostic scans.

Feasibility and accuracy of the correction method were investigated for neuro examinations with 5 healthy volunteers. A fast gradient echo sequence (FOV 256×256 mm^2, in-plane resolution 4×4 mm^2, slice thickness 20 mm, flip angle 3°, TR/TE 3.61/1.59 ms) was used as the tracker scan. The flip angle was chosen as low as possible to avoid saturation interference between the tracker and the consecutive diagnostic scans. The rigid 2D registration used cross-correlation as similarity measure. Acquisition time for one set of 3 orthogonal tracker slices was 280 ms, while each 2D registration took 10 ms on average, so that a complete iteration was done in 290 ms.

Experiments were performed on a clinical 1.5T scanner (Achieva, Philips Healthcare) and a clinical 3T scanner (Ingenia, Philips Healthcare), both using a multi-channel head coil. The same diagnostic scan (T2-weighted multi-slice turbo spin echo acquisition; in-plane resolution 0.5x0.5 mm^2, slice thickness 5mm) was performed three times for each volunteer: First, at the beginning of the session, after the reference tracker was acquired; then, two times after the volunteer was instructed to slightly move his head: once with and once without motion correction.

Results: The geometry could be tracked successfully in all cases. Figure 1 shows a selected transversal slice of the diagnostic turbo spin echo scan at 3T. While the images acquired before the movement (a) and after the movement with motion correction (b) show good alignment, the image after the movement without correction (c) depicts a different location.

In order to measure the accuracy of the proposed correction method, the two scans acquired after motion were retrospectively registered individually with the scan acquired before motion. The mean absolute displacement field, computed over all brain voxels, was taken as measure of the residual error for the scan acquired with motion correction and as a measure of the overall head displacement for the scan acquired without motion correction. Minimal, maximal, and mean displacements obtained with and without motion correction over the 5 volunteer cases are shown on Figure 1d. The error bars represent the standard deviation over all volunteers.

Discussion and Conclusion: The proposed tracking method is a simple and generic approach to cope with rigid motion between different scan elements for a number of contrast types and was shown to correct for head motion on both 1.5T and 3T systems effectively. Since the geometry update generally requires only a few seconds, the overall scan time is only slightly prolonged. It might be useful also for other anatomies suffering from rigid motion, e.g. musculoskeletal MRI. Due to the use of an interleaved data acquisition system for the implementation, all scan protocol parameters of the tracker scan, i.e. contrast, flip angle, resolution and FOV can be adapted with full flexibility. Once the tracker scan is planned, the motion compensation is performed automatically without any additional user interaction.

References:

[1] Nielsen, et al.: ISMRM 2012, 2472; **[2]** Welch, et al., MRM 52: 1448 - 1452 (2004); **[3]** Henningsson et al. MRM to be published: A New Framework for Interleaved Scanning in Cardiovascular MR: Application to Image-Based Respiratory Motion Correction in Coronary MR Angiography

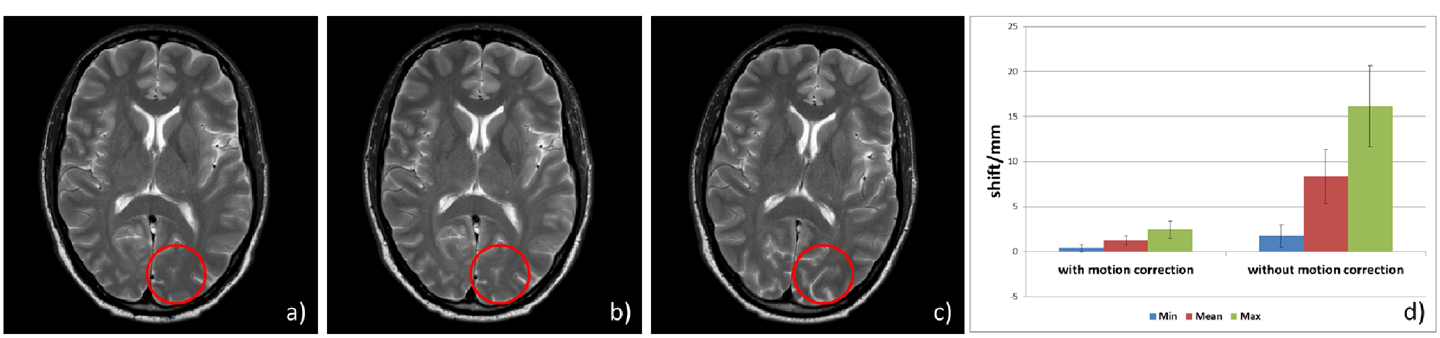

Figure 1: Selected slice from a diagnostic turbo spin echo scan (3T): a) before motion, b) after motion with correction, c) after motion without correction. The red circle indicates through-plane motion. d) Statistics of the mean displacement over the 5 volunteers with and without correction.