Improved Tracking of Object Motion During MRI Examinations Using Coil Fingerprint Enhanced Signal Navigators.

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Target Audience: Researchers involved with motion tracking, gated imaging techniques and hybrid MR and PET imaging.

Purpose: To provide a fast and improved means to identify motion states during an entire, multi-dimensional, multi-contrast, MRI exam through the use of coil-sensitivity-enhanced navigator "fingerprints".

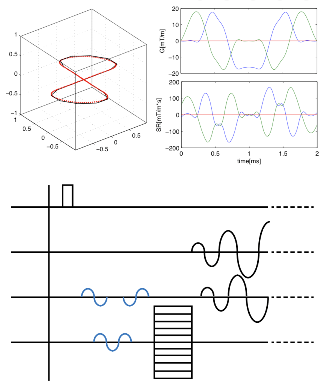

Fig 1: Sketch of the bowtie navigator trajectory and the corresponding motion calibration 3D spiral sequence.

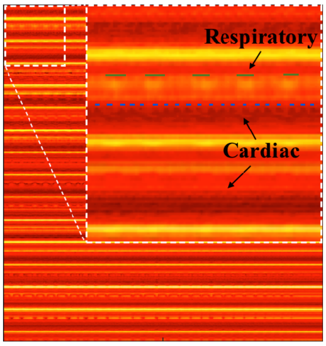

Fig 2: Navigator database. Both respiratory and cardiac cycles can be seen through close visual inspection as the zoomed view well depicts.

Methods: The method requires the use of a navigator signal that can be collected during a "motion calibration" scan as well as during conventional diagnostic sequences (e.g., Turbo Spin Echo (TSE), Spin Echo (SE), etc). For this purpose, 1.0ms 2D bowtie-shaped navigators [1] were inserted between the slab-selective RF-pulse and the readout segments of 3D gradient echo and FSE sequences. The 3D gradient echo sequences were used for motion calibration. For these sequences, TE and TR were, generally, chosen to exhibit proton density contrast. This choice allows the navigator signal to be easily mapped to a motion state during the acquisition of other diagnostic sequences (e.g., FSE) by placing the navigator close to the slab selective pulse. Figure 1 presents a sketch for one such implementation for the "motion calibration scan" using a spiral readout. In this implementation, the navigator signal consisted of a self-refocused, 3.2ms long, trajectory. Image generation was achieved using a stack of spirals with golden-angle-rotated spiral arms (3 interleaves per plane, FOV of 400x400x256mm^3, resolution 3.1x3.1x4mm and 7° flip angle). Data were acquired at multiple bed positions for ten different subjects using a 15-element (8 frontal and 7 dorsal) body array. Nyquist acceleration (factor 3.0) was also used to reduce the acquisition of a single volume to less than 1 second. This calibration sequence was then used to "characterize the motion". During this step, the combined signature or "fingerprint" [2] from the navigator signal from all coils was used to map signal from each TR to one of 30-40 distinct volumes representing 30-40 distinct motion states. This motion "dictionary" was then used throughout the duration of the exam to assign the readout data from each TR to a specific motion state via the Euclidean distance between its fingerprint and that of the reference in the dictionary.

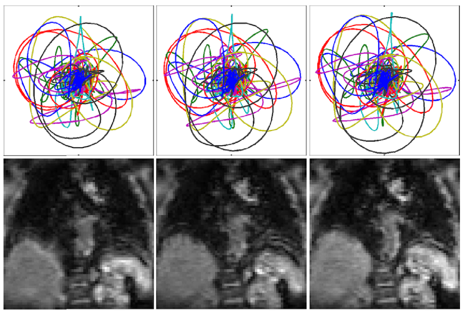

Fig 3: Three, 16-channel, complex valued coil fingerprints and their corresponding motion states.

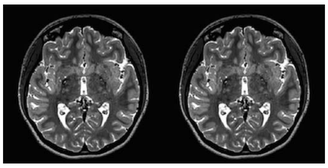

Fig 4: Comparison between (left) conventional and (right) bowtie-navigated 3D TSE scans (TR=3200ms, TE=400ms, 140 echoes). The addition of a navigator signal each 10th echo led negligible (18 sec) scan time increase.

Results: Figure 2 presents a visual rendition of the dictionary signal from a calibration scan obtained using the spiral sequence sketched in figure 1. Using this dictionary, a set of forty different motion states was synthesized. Three of the corresponding motion states are illustrated in figure 3 alongside polar plots of their corresponding coil fingerprints. Note that despite some overall similarities, the corresponding fingerprints are distinct and sufficient to accurately identify their corresponding motion states. To evaluate the interplay between the navigator signal and the contrast sought for using clinical TSE sequences we acquired images with and without the presence of a navigator signal. These results are presented in figure 4 and, as expected, the self-refocused nature of the navigator signal preserves the contrast of the un-navigated TSE acquisition. The improved motion tracking performance of the coil fingerprint approach is illustrated in figure 5. In this figure, two different motion-tracked volumes were obtained from the same dataset by tracking (left) the coil fingerprints and (right) the center of k-space from the navigator signal. This latter approach has been used previously [3] for correcting and/or navigating free-breathing body scans. Because the center of k-space effectively tracks the center of mass of the excited volume, it has only limited effectiveness to monitor the complex nature of the elastic deformations taking place during a free breathing scan.

Discussion: As shown above, short, self-refocused, multi-dimensional navigators are an attractive means to monitor non-rigid body motion in the body. The self-refocused nature and short duration of the navigators used here make them well suited for use in conjunction with high duty cycle imaging sequences as each excitation provides an opportunity to obtain motion tracking signal. As many of the sequence in the body MRI armamentarium are high duty-cycle, this approach can potentially be used to provide motion tracking information throughout the majority of a body MRI examination. This latter fact makes this approach particularly useful in the context of concurrent MR-PET scans, where continuous motion updates are highly desirable [4].

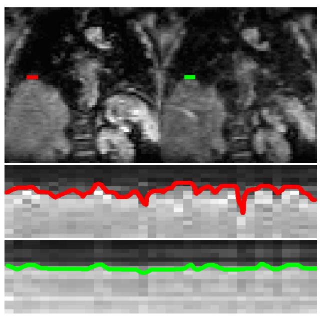

Fig 5: Motion estimation for the diafragm tracking in images corrected utilising coil-navigating fingerprints (left) and using the method suggested by [3] (right).

Conclusion: We have demonstrated an effective approach for continuous tracking of motion during clinical body MRI examinations. The proposed approach improves over previously introduced means to monitor three dimensional motion fields using MRI [1]. Because of its continuous nature, this approach is ideally suited for motion compensation during hybrid MR-PET scans.

References: [1] Lustig M et al., ISMRM 2007, pp. 865. [2] Ma D et al., Nature, 495:187, 2013. [3] Feng L et al., ISMRM 2012, pp.81. [4] Koesters T et al., ISMRM 2014, pp. 789.