Motion detection for 3D radial balanced SSFP sequences

Matthias Schloegl[1], Clemens Diwoky[1], and Rudolf Stollberger[1]
[1]*Institute of Medical Engineering, Graz University of Technology, Graz, Austria*

Introduction: Magnetic resonance imaging is highly sensitive to motion, which is even worse for 3D acquisition schemes due to prolonged scan time. For many applications that are prone to corruption by motion artifacts it is essential to have access to information about the motion in order to render correction possible. This work presents a novel intrinsic motion information detection technique for balanced 3D radial SSFP imaging sequences [1] not requiring external monitoring devices such as ECG recording or internal navigators. Therefore obstacles in patient preparation or time-issues can be mitigated in clinical practice. The method was validated in two ways leaded by potential applications: In the first case of cranial motion the author used low-resolution navigators (LRN) inspired by the PROMO [2] navigator technique adapted to 3D golden-ratio sampling. In the second example of cardiac motion the detection scheme was compared to the recorded ECG signal.

Methods: Head motion was introduced in a pseudo-periodic way within the transversal plane by slow rotation of the head (about one period in four seconds) from left to right with an approximate maximum angle of 15°. Data was acquired on a 3T Siemens Skyra System. Scan parameters included: TR = 3.33 ms, TE1/TE2 = 0.55/2.75 ms, rBW = 980Hz/px, flip angle = 25°, voxel size 1.7 mm isotropic, 220 mm cubic imaging volume with 2 times 16381 projections corresponding to a 128x128x128 matrix for a total scan time of 58 s. Cardiac imaging was performed with breath-hold on a volunteer with the following scan parameters: TR = 2.21 ms, TE1/TE2 = 0.1/1.6 ms, BW = 1.62 kHz/px, flip angle = 37°, voxel size 2.2 mm and 140 mm isotropic FOV resulting in 18 s of total scan time with two times 8192 projections. Motion information detection is based on analysis of the deviation between inherently given first-(FE) and late-echoes (LE) containing the same spatial encoding. The used metric to discriminate these deviations is the maximum absolute difference between FE and LE in a given TR for a manually selected receiver channel located close to the heart, resp. showing best discriminative power in the case of head motion.

$m_n[s_n^{FE}, s_n^{LE}] = \max\,[abs(s_n^{FE}) - abs(s_n^{LE})].$

where n denotes the current spoke-index and s_n^{FE} resp. s_n^{LE} the recorded FE- and LE-signal for spoke n. For the evaluation of cranial motion, values were compared to a motion free reference and signal variations were detected with a peak detection algorithm implemented in MATLAB. (Fig 1) For each LRN image central frequencies satisfying the Nyquist limit from 100 subsequent acquired spokes were used for reconstruction, which corresponds to a time resolution of 356ms per frame. Golden-ratio radial sampling [3] guarantees uniform k-space coverage. Only the central transversal slice of a whole 3D navigator image is displayed due to motion limitations to this plane. In order to evaluate the cardiac test case, maximum difference values were band-pass filtered (40-250 Hz) prior to the use of a peak detection algorithm to create an ECG surrogate (Fig 2). The acquired ECG data was aligned to the sequence timing with build-in timestamps.

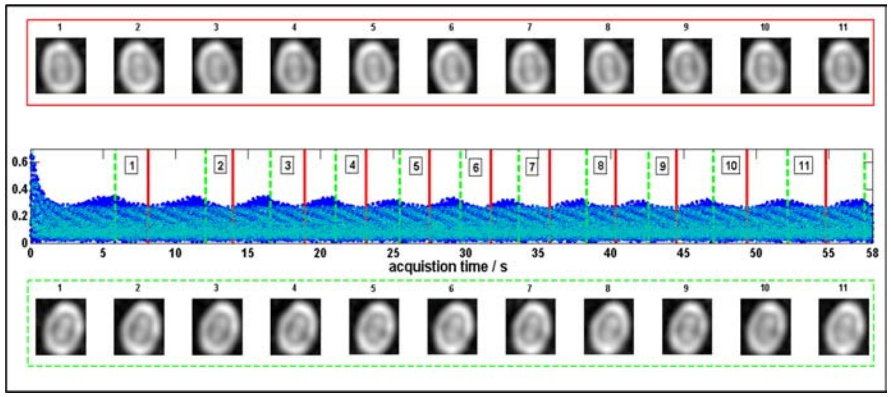

Fig 1: Axial slides of low-resolution navigators (first and third row) corresponding to maxima (green-dashed lines) and minima (red solid lines) found in normalised FE/LE analysis of left-right head motion dataset (dark-blue) compared to motion-free reference scan (light-blue). A offset due to convergence to a steady state is apparent.(up to ~ 2.5 s)

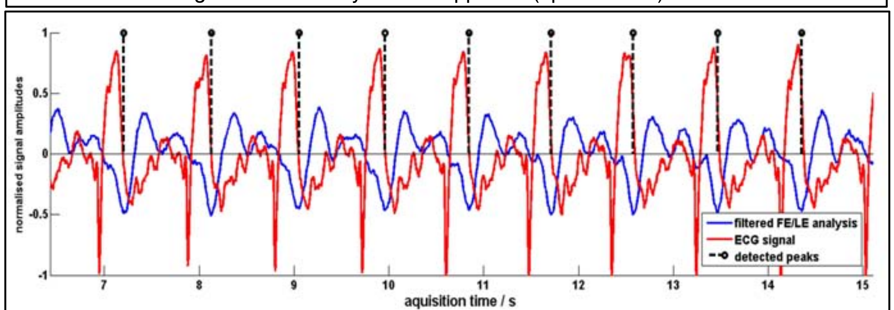

Fig 2: Normalised band-pass filtered FE/LE analysis (blue solid line) compared to recorded ECG signal (red solid line) and detected peaks on the basis of minima of FE/LE ECG surrogate (black dashed line)

Results and Discussion: Figure 1 clearly shows periodic alterations in the maximum difference values due to the described head motion in distinction to the motionless reference values. This is emphasized by the LRN images, demonstrating that maxima and minima correspond to the same orientations of the head. In the case of real periodic cardiac motion this fact proves even more valuable, easily establishing an ECG surrogate (Fig 2) that can be used for self-gating techniques ([4],[5]) without any additional ECG recording. Furthermore the signal exhibits higher agreement with the physiologic heart movement than the delayed ECG signal where the contraction of the ventricles is followed shortly after highest electrical activation activity of the heart (QRS complex). Nevertheless the chosen metric is very simple and will be investigated further concerning possibilities to yield quantitative motion information. Also it is thought possible to include information from multiple receiver coils as in [6]. Lastly the results show how severely intra-shot motion, e.g. motion occurring within repetitions, alters the MR signal on such a short time-scale (TR<5ms). This permits the use of the described method for motion detection on lowermost time-scales.

References: [1] Rahmer J. et al, MRM, 2006, 55:1075-1082 [2] White N. et al, MRM ,2010, 63:91-105 [3] Winkelmann S. et al, IEEE Trans Med Imag, 2007, 26:68-76 [4] Larson A. et al, MRM, 2004, 51:93-102 [5] Anderson III A. et al, MRM, 2013, 69:1094-1103 [6] Kober T. et al, MRM, 2011, 66:135-143 **Acknowledgments:** This work was supported by the Austrian Science Fund (FWF) under grant SFB F32