Self-Navigated Motion Detection Technique Generalized for Arbitrary Pulse Sequences

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Introduction: Patient motion during MRI causes image artifacts that compromise the diagnostic utility of the scan. Most motion artifact reduction techniques require the ability to measure motion during the scan, either by external physical means (e.g. respiratory bellows, electrocardiogram) or by interleaving extra gradient pulses into the pulse sequence (e.g. navigator echoes)—tasks that impose additional scan time and/or complexity. Furthermore, externally acquired measurements are often indirect gauges of motion that may not accurately reflect motion in the volume of interest.

Recently, "self-gated" techniques have been reported that derive retrospective cardiac gating signals from MR data during SSFP imaging [1,2]. These methods require gradient rewinders to produce a second, non-phase-encoded echo [1] or the use of a radial trajectory [2]. We extend this work and present a flexible self-gated motion detection technique that is generalized for a variety of pulse sequences and k-space trajectories. The extracted motion information could be used with a variety of motion artifact reduction techniques, including synchronization of image acquisition with motion or the correction of data acquired in the presence of motion. Initial feasibility of the self-navigated motion detection technique is demonstrated in the abdomen, and results are correlated with respiratory bellows measurement.

Methods: The proposed technique exploits the fact that the k-space trajectory of virtually all pulse sequences inherently begins at the k-space origin. Immediately after RF slice selection and gradient refocusing, spins in the excited slice are maximally coherent prior to the onset of spatial encoding gradients. The magnitude of the DC signal sampled at that instant represents the integrated intensity of all transverse magnetization in the slice of interest. Thus, assuming the spin system is in steady-state, any change in this value over time can be attributed to motion-induced changes in magnetization. By repeatedly sampling this DC data during imaging, information about patient motion can be extracted directly from the raw MR signal in a "self-navigated" fashion [3].

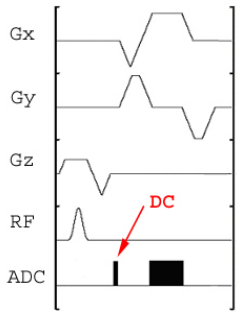

Figure 1. Pulse sequence of a self-navigated FGRE Cartesian trajectory. The ADC is turned on to capture the k-space origin immediately after slice selection (arrow). Note that no additional gradient pulses are applied; only appropriate timing of the ADC is needed to sample the DC data.

A sample gradient echo Cartesian pulse sequence incorporating the self-navigated method is illustrated in Fig. 1. The A/D converter (ADC) is turned on immediately after slice selection (arrow) to acquire a few points of the FID at the k-space origin, after which spatial encoding and data acquisition occur as usual. No additional gradient lobes are required; the only modifications necessary to sample the k-space origin are the appropriate timing of the ADC, and if necessary, the delay of x -and y- gradient prewinders so as not to overlap the slice refocusing lobe. This delay results in a nominal TE increase of no more than a few hundred μs, depending on slew rate, slice thickness, etc.

Imaging was performed on a 1.5T scanner (Signa TwinSpeed, GE Healthcare, Milwaukee, WI) using an 8-channel torso coil. A standard 2D fast gradient echo (FGRE) pulse sequence was modified to sample the k-space origin every TR interval, as in Fig. 1. Abdominal free-breathing and breath-held axial imaging was performed on three volunteers with approval of our Institutional Review Board. A respiratory bellows signal was simultaneously recorded during the scan. Data was analyzed offline using Matlab (MathWorks, Natick, MA). As each slice and coil experience different sensitivity to motion, DC data from the slice and coil exhibiting maximum signal fluctuations were compared to the bellows signal.

Results:

Figure 2a compares sample DC data (blue) to respiratory bellows data (red) acquired during free breathing. Fluctuations in the DC signal are consistent with the bellows data, supporting the hypothesis that breathing motion information is contained within the raw MR signal. The corresponding image data is shown in Fig. 2b. As expected, breathing artifact is visible as blurring across the image and ghosting near the anterior chest wall. Figure 2c compares DC data (blue) to bellows data (red) acquired during a 33-s breath-hold. Low frequency fluctuations due to breathing motion seen in Fig. 2a are absent from the breath-held DC data in Fig. 2c, as predicted. In addition, the DC data shows high frequency oscillations presumably due to pulsatile blood flow, revealing the sensitivity of the method to various types of motion-induced magnetization modulation. The corresponding image in Fig. 2d confirms the presence of discrete pulsatility ghosts from the descending aorta and inferior vena cava (arrows).

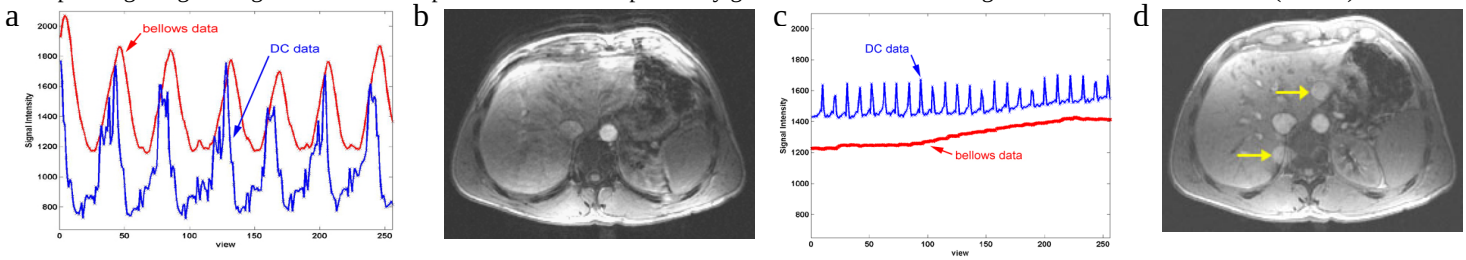

Figure 2. a) DC data vs. bellows data acquired during free-breathing. b) Corresponding slice from which data was extracted. c) DC data vs. bellows data acquired during a breath-hold, showing reduced breathing fluctuations but also apparent cardiac pulsatility. d) Corresponding slice shows reduced breathing artifact and pulsatility ghosts of the descending aorta and inferior vena cava (arrows). TE/TR = 6.4/110ms, FOV=40cm, sl=7mm, 256x256, BW=62kHz, α=90°.

Discussion:

The self-navigated method is shown to detect both breathing motion and cardiovascular pulsatility from raw MR data acquired during axial abdominal imaging. Initial results suggest that the technique will also be applicable for other slice orientations. The proposed technique eliminates the need for external physiological measurement by directly and efficiently detecting motion from the volume of interest. Future work will elucidate which applications may benefit most from this method. Potential applications include respiratory-triggered body imaging, cardiac-gated coronary imaging, phase correction of motion-corrupted data, and slice tracking.

References:

[1] Crowe M, et al. Magn Res Med 52:782-788, 2004. [2] Larson A, et al. Magn Res Med 51:93-102, 2004. [3] Glover G, et al. Magn Res Med 39:361-368, 1998.