Real-time prospective rigid-body motion correction with the EndoScout gradient-based tracking system

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Introduction and Background

Motion during MR acquisitions causes considerable wasted scan time and can confound diagnosis in clinical scans [1,2]. We present an integrated solution for tracking and correcting rigid body motion in real-time using the EndoScout gradient-based tracking system (Robin Medical Inc., Baltimore, MD) and the Siemens TIM Trio MR scanner (Erlangen, Germany).

The EndoScout system uses a 1 cm cubic sensor, with a pickup coil on each face, to detect changing magnetic fields induced by the switching gradients used during imaging. With suitable signal conditioning, and appropriate processing relating the scanner's signals driving the gradient power amplifier to the measured induced voltages in the pickup coils, the system is able to determine the position and orientation of the sensor inside the scanner bore. This requires that all gradient axes be activated at some time during the measurement window, which may be as short as several milliseconds. This condition is satisfied by some standard sequences, and additional gradients can be added to most other sequences to provide robust activation of all axes throughout the scan without affecting image quality. This approach is considerably less invasive than navigator echoes [3,4]. If the particular scanner model's gradient fields are mapped when the system is installed, the position and orientation of the sensor can be accurately tracked even within the less linear regions of the gradient fields further from the scanner isocenter.

Methods and Results

We set up an Ethernet connection between the EndoScout system and the scanner measurement control and image reconstruction (MCIR) computer to provide position and orientation estimates on request during a running scan. We modified the standard Siemens spoiled gradient echo (FLASH) sequence by inserting an additional gradient pulse on each axis in turn during the time between the readout and the next RF excitation pulse every TR (Figure 1), and adapted the image reconstruction code to request a sensor position estimate every TR and feed it back to the gradient control computer to reorient the gradients during the following TR and thus track the sensor position and orientation and motion-correct the scan, in real time. We also modified the reconstruction to display the sensor position and orientation as a DICOM overlay.

We rigidly attached the sensor to a pineapple on a moving platform inside the 12-channel matrix head coil. Figure 2 shows the position of the sensor relative to the pineapple. Note that the sensor is adjacent to the pineapple and not embedded within it, therefore the slice showing the sensor does not contain an image of the pineapple (an adjacent slice is shown for reference). The images showed no visible artifacts induced by the sensor.

The platform was manipulated remotely during a series of 2D acquisitions in two ways: the pineapple was smoothly rotated back and forth through an angle of ±4˚, and it was abruptly repositioned at either extreme every 12 seconds. Figure 3 show the sinusoidal translations and rotations of the sensor (and pineapple) measured during the smooth motion. During each scan, repeated single slices of a 2D FLASH scan were collected (TR 15 ms, TE 3.76ms, FA 15˚, 1 mm^2 in-plane, FoV 160 mm, 5 mm slice thickness, 30 measurements) to produce a movie of the pineapple showing the residual motion with and without motion correction. Figure 4 shows the averages of the 2D acquisitions during the two types of motion.

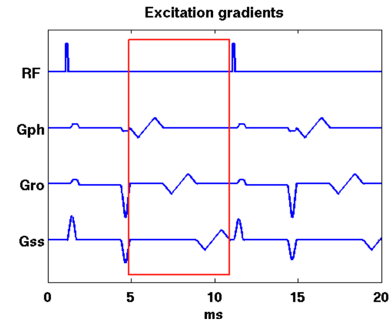

Figure 1: Excitation gradients inserted in FLASH sequence.

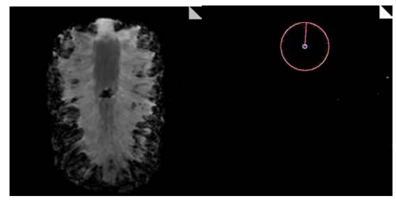

Figure 2: Center slice of pineapple (left) and distal slice adjacent to pineapple (right) containing EndoScout sensor. Position and orientation of sensor are shown as a DICOM overlay (right).

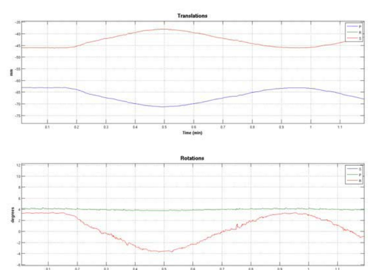

Figure 3: Translations and rotations measured and corrected every TR during smooth periodic motion.

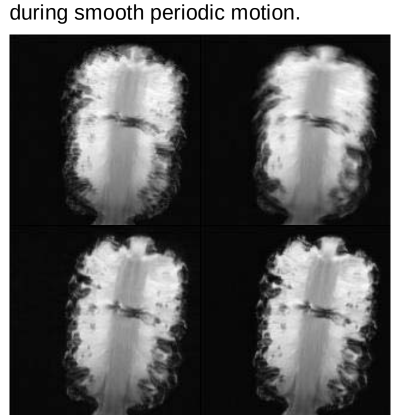

Figure 4: Average of 30 acquisitions without motion correction during step motion (top left) and smooth motion (top right); average with motion correction during step motion (bottom left) and smooth motion (bottom right).

Conclusion

We verified that no visible artifacts are induced in slices of MPRAGE and EPI scans proximal to the EndoScout sensor due to induced B0 field inhomogeneities or in any slices due to RF interference. We verified further that the position and orientation of the sensor is correctly reflected in the marker superimposed on the DICOM images. Finally we demonstrated that the EndoScout system can be integrated with a 3T TIM Trio scanner to provide real-time motion tracking and correction in 2D sequences of images.

In other tests not described above, we verified that motion tracking is possible during 3D FLASH scans and that the system also operates accurately in the less linear gradient fields of the wide-bore Siemens 3T Espree scanner. We also verified that the additional excitation gradients may be eliminated while tracking performance is maintained during FLASH acquisitions if the phase encoding order is interleaved or randomized.

Acknowledgement

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References

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