Real-time projection based technique for tracking ferromagnetic devices

E. Aboussouan[1], O. Felfoul[1], J-B. Mathieu[1], G. Beaudoin[2], S. Martel[1]

[1]Biomedical engineering, École Polytechnique de Montréal (EPM), Montréal, Québec, Canada, [2]Department of Radiology, Centre Hospitalier de l'Universite de Montréal (CHUM), Montréal, Québec, Canada

Introduction

A tracking technique for an untethered microdevice based on the MRI signal acquisition and imaging capabilities is described. This microdevice aims at being propelled by magnetic gradients generated by a clinical MRI system and is mainly composed of ferromagnetic materials. Being able to use the MRI for the propulsion as well as the tracking by temporal multiplexing is of great interest since this solution becomes more practical to implement in hospitals. Unfortunately, all the passive tracking techniques already reported in the literature [1-3] are inadequate for this application because of two major limitations being the poor temporal and spatial resolution. In fact, real time control of such a device requires a high position update rate as well as a high spatial resolution. Here, a novel tracking method proposed uses the induced magnetic field of the ferromagnetic device. This technique, dubbed MSSET (Magnetic Signature Selective Excitation Tracking), excites a volume with an RF tuned to a particular frequency, different from the surrounding and specific to the device's induced field. The primary results achieved, with a static ferromagnetic chrome steel sphere, demonstrate the potential of this technique.

Method

Real time implementation, however, brings new difficulties that can be problematic for tracking. For example, the effect of motion during RF excitation can have an impact on the flip angle experienced by the spins. Furthermore, only some of the excited spins will experience the refocusing pulse. Finally, magnetic inhomogeneities will shift the echo time because the induced magnetic field will not be correctly balanced by the refocusing pulse. In order to quantify these errors, the MRI positioning data was compared with the results obtained by an optical tracking system consisting of a PIXELINK CAPTURE SE camera. The trajectory traveled by the ferromagnetic sphere was filmed and then the TTL output of the Siemens AVANTO MRI system was used to synchronize the sequence with the camera. MSSET employs a Spin Echo (SE) sequence with the slice select gradient removed. The spin echo implementation corrects for the dephasing caused by the magnetic field inhomogeneities. The sequence parameters were: TE = 9.8 ms, flip angle = 90º, frequency offset = 1,000 Hz, a refresh rate of 10 projections/second, 1024 sampled points in the read direction, and a FOV in the x direction of 300 mm resulting in a pixel size of 0.293 mm. The ferromagnetic device was mounted on the tip of a catheter and was moved manually. Positions were found by correlating each new projection with the first one acquired, which was considered as the reference. The trajectory given by the camera was obtained by manually sketching the pixel coordinate of the sphere in each frame.

Results and discussion

Previous results made with a static sphere give an average error of 0.064 mm between the real position and the measured one. In the dynamic case, however, this value is found to be approximately 1.2 mm. As far as we can see, this is mainly due to the short relaxation time left to the spins to return to their equilibrium state. In fact, Figure 2 shows that the SNR decreases from nearly 40, for the first projection, to 3.25, for a projection taken 7 seconds after the beginning of the tracking. Even if the position of the ferromagnetic device changes in time, the SNR remain as low as 3.25 for all subsequent projections. However this is enough to track the device efficiently, as depicted by Figure 3, where the trajectories obtained through both MRI projections and optical means are superimposed.

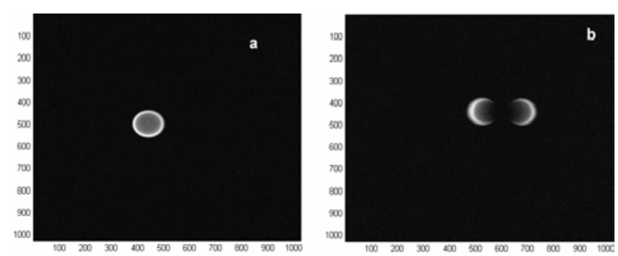

Fig 1: MRI images of the ferromagnetic sphere with MSSET method in the transversal (a) and in the sagittal plane (b). The offset RF frequency was 2 kHz and its duration was 2560 µs. Imaging parameters was TR/TE = 150/7.5 ms, 1024×1024 and a FOV = 300×300 mm.

Conclusion

A proof of concept for a novel tracking technique of a moving ferromagnetic device was presented. This method is to be implemented in a real time sequence with feed back control in order to control the position of the ferromagnetic device by gradient adjustment.

Acknowledgment

Natural Sciences and Engineering Research Council of Canada (NSERC).

References

[1] R. van der Weide and al. IEEE Trans. Med. Imag., vol. 20, n. 10, pp. 779-785, Oct. 2001.
[2] J-H. Seppenwoolde and al. MRM, vol. 50, n. 4 pp. 784-790, Oct. 2003.
[3] O. Unal and al., MRM, vol. 40, n. 3, pp. 356-62, Sep. 1998.

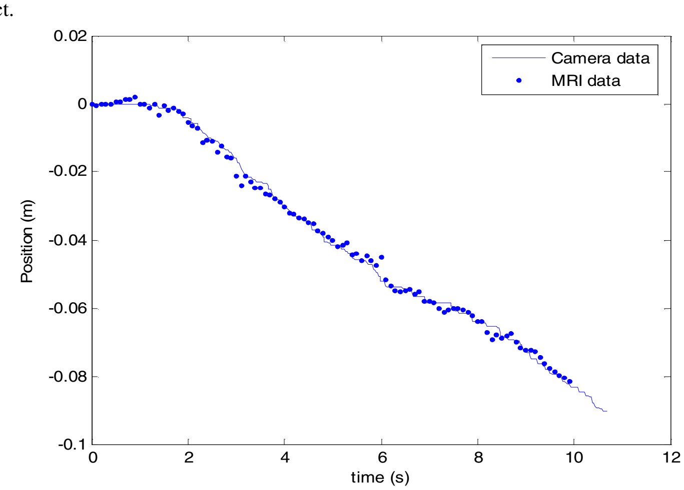

Fig 3: The trajectory traveled by the ferromagnetic sphere as given by the camera and the correlation of MRI projections.

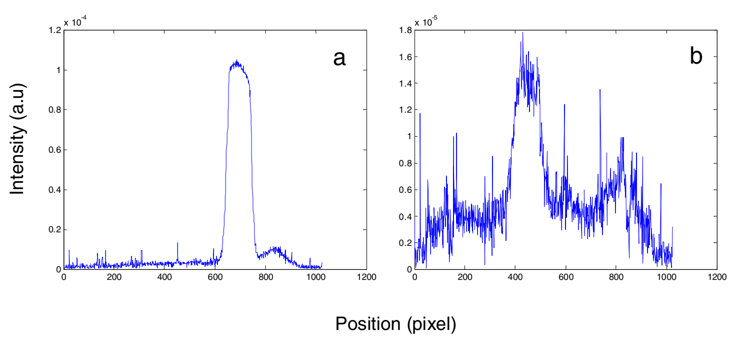

Fig 2: (a) first projection, (b) projection after 7 seconds.