Low-Cost MRI Compatible Interface Device for Interactive Scan Plane Control

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Introduction

When using MRI to guide interventions, interactive adjustment of scan plane orientations is needed. Frequently, this is achieved through verbal communication between the interventionist and a scanner operator outside the MRI room. In some cases it would be desirable to have the physician be able to control the scan planes directly from inside the scanner room, but the currently available interface devices (mouse and keyboard) are not well suited or compatible with the MRI environment. Here we present a low cost interface device, which is built from readily available off-the-shelf components and which is compatible with the MRI environment. With this device in-hand, the physician is able to control the rotation and translation of the scan planes using a combination of gestures with the device and a foot-pedal to activate and deactivate the device and to determine the slice being controlled.

Materials and methods

The solution consists of off-the-shelf hardware combined with custom software that permits the clinician to manipulate the scan plane from inside the MRI room. The shielded device comprises a gyroscope and accelerometer combination board (6DOF Atomic, Sparkfun Electronics, Boulder CO) connected over USB (See Fig. 1 and 2). Information about device rotation is derived from the gyroscope readouts and translation information is determined by integration of the accelerometer output. The electronics of the device were covered with a copper tape shield and enclosed in a custom built plastic casing. A three button foot pedal (Kinesis Corporation, Bothell, WA. 98021-7404, USA) enables the physician to a) start and stop the acquisition (pause), b) identify which slice is currently being controlled by the interface device, and c) activate the interface device. As an example usage scenario, the physician would pick up the device, activate it with the foot pedal, change the slice orientation, verify the new slice location on an interactive MRI display, and deactivate the device (by releasing the foot pedal). The control of scan plane orientation can be chosen to be either relative to the patient, or relative to the view plane displayed on the screen. This option is selectable from a configuration menu according to the preference of the operator. The custom control software is implemented in Python (v2.5). Errors and noise from the hardware are filtered (Kalman filter) before sending out the new positions to the scanner host using a TCP/IP connection. The system was tested on a Siemens Espree, short, wide-bore 1.5T system (Siemens, Erlangen, Germany). The performance of the system was investigated by rotating the device by predetermined increments and observing the actual change in scan plane orientation. The total cost (materials) for building the control system was $130 for the interface device and $149 for the foot pedal.

Results

The proposed device was capable of rotating the scan planes accurately, with the average error on the order of 1% (see tables below). The performance for translation was more difficult to quantify. Accelerometer drift made it more difficult to achieve an accurate relationship between displacement of the device and the scan plane. An algorithm for mitigating this problem is the subject of future work. In practice, the visual feedback provided by real-time MR imaging, significantly assists the operator in obtaining anaccurate and precise scan plane adjustment during interactive scanning.

Rotation Errors:

Roll	Result (Degrees)	Expected (Degrees)	% Error
	90.2	90	0.22
	90.7	90	0.78
	91.1	90	1.22
	89.8	90	0.22
	90.3	90	0.33
Average			0.56

Yaw	Result (Degrees)	Expected (Degrees)	% Error
	90.3	90	0.33
	90.6	90	0.67
	90.2	90	0.22
	90.7	90	0.78
	90.5	90	0.56
Average			0.51

Pitch	Result (Degrees)	Expected (Degrees)	% Error
	91.4	90	1.56
	90.9	90	1.00
	90.8	90	0.89
	91.2	90	1.33
	92.8	90	3.11
Average			1.58

Compatibility with MR environment:

The magnetic field of the scanner did not appear to have any influence on device performance when held close to the scanner bore (<0.5m). The image quality also did not appear degraded in terms of signal to noise ratio or artifacts. Quantitative measurements to verify the image quality are the subject of future work.

Conclusion

We have presented a simple system for in-room control of scan planes. The system is built from low cost, off-the-shelf components and would be straightforward to integrate with most available MRI systems. At present, this is a work in progress and more rigorous testing and physician feedback is required to fine-tune the system before it could be used in a clinical workspace. Work is also ongoing to improve the robustness of the translational motion component of the system. A significant advantage of the proposed system is that it is relatively simple and cheap to modify the device (e.g. physical shape, sensitivity to motion etc.) to suit different preferences of different physicians or to customize it for a specific interventional application

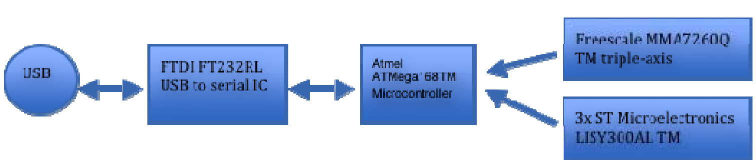

Figure 1: Device operation

Figure 2: The accelerometer and gyroscope device

Figure 3: Foot pedals to assist with the main device