Automatic Device Tracking: A Multi Slice Approach

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Introduction

Interactive real time MRI has been successfully demonstrated in MR-guided interventions [1-2] using active devices either for visualization or tracking [3]. Dedicated devices and fully integrated scanner software with a range of real time capabilities such as arbitrary, oblique scan plane selection, automated device tracking and device plane localization as well as visualization of reference anatomy are critical factors when performing MR-guided interventions. In this work, a generalized interactive multi slice sequence with tip tracking capability is presented. The sequence allows the real time selection of multiple slices in oblique orientation with an interactively user selectable update frequency. For example, a central slice containing the device is updated more frequently to enhance device tracking and an outer slice is used to visualize a relatively static anatomy. Real time updates of a slice can be turned on or off as required by the complexity of the anatomy and stage of the intervention. Device position can be displayed in all or only selected slices. This work demonstrates these features in a vessel phantom study using a commercial grade catheter (Interventional Imaging, Inc. Cleveland, Ohio).

Material and Methods

Sequence Design: Multi-slice capability was integrated into a previously described interactive sequence (Sonata, Siemens Medical Solutions, Erlangen, Germany) that provides dedicated functionality for interventional applications [4] (Fig. 1a). The sequence is using the standard user interface and image reconstruction system of the scanner. A real time parameter was added to the standard user interface describing the slice acquisition scheme. For example, the update string 112 indicates that slice 1 is updated at twice the rate of slice 2. Changing the string in real time to 1, switches off the update for slice 2.

A tracking module acquired three orthogonal projections (5° flip angle) between two consecutive images using the well-known *z*-dephaser (2mT/m) and $\alpha/2$ pulses to preserve the steady state in case of a trueFISP contrast [5]. The position and orientation of one particular or all slices could be updated in real time using the position information derived from the acquired projections.

Catheter Design: Various coils designs for imaging, visualization and tracking have been proposed [5, 6]. In this work, a commercial grade 5 Fr catheter (1.66 mm OD) utilizing the counter-solenoid geometry was used. This catheter is well suited for tip tracking because its signal is highly localized in all 3 dimensions, yet has the ability to deliver high-resolution images of the target anatomy, such as vessel wall in the study of vulnerable plaque. The matching, tuning and decoupling circuitry, consisting of 0201 sized capacitors and diodes, were integrated into the tip of the catheter. The counter solenoid coil was constructed on a hollow former to allow for a lumen accommodating a 0.014'' guide wire. The counter solenoid coil is connected to an interventional scanner interface via an integrated micro coaxial cable. RF cable traps were used to suppress shield currents along the connection cable. The interventional interface contains preamplifiers, decoupling circuits and additional cable traps. Both decoupling circuits and cable traps are required to suppress RF heating.

Phantom Study: The catheter was inserted into a vessel phantom (plexi glass tube, inner diameter 8 mm) emerged in $CuSO_4$ solution (1.25 g/liter). The catheter was advanced during real time imaging (Fig 1a, frame rate ~3 fps). Two orthogonal slices contained the tip of the catheter and automatically shifted into the coils position. The tip-tracking coil was either visualized by a cross in the image or by using the tip tracking coils for image reconstruction. During measurement the slice alternation scheme was changed or particular slices were switched on and off.

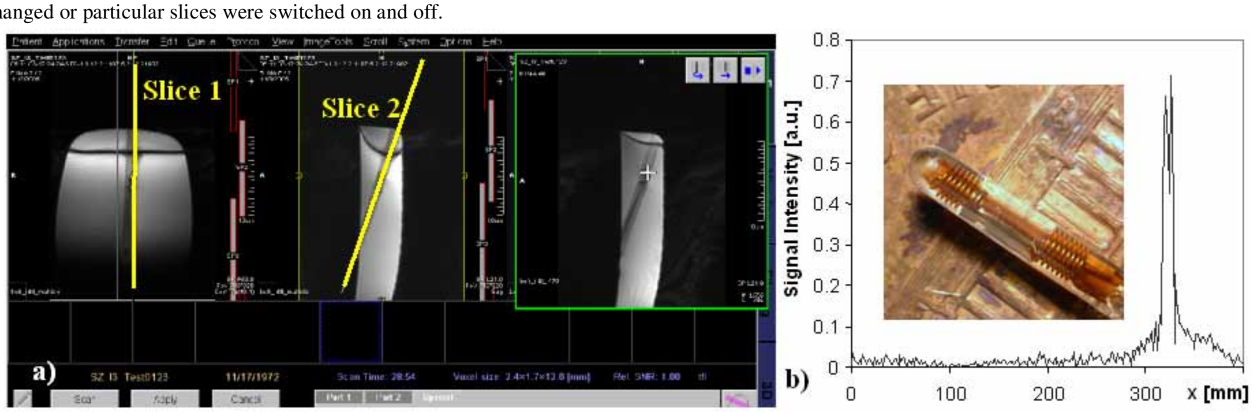

Fig. 1: *(a) Multi slice sequence. Two orthogonal slices were prescribed using the graphical slice-positioning tool. During the measurement, the slices were shifted automatically to capture the device plane. Slices and acquisition scheme were changed in real time. The cross indicated the tip of the catheter. (b) Tracking Signal and Tracking coil (on a cent coin): An opposed solenoid design with tuning/matching and decoupling network integrated in the tip of a 5 Fr catheter.*

Results

A peak-to-noise ratio of approximately 60 was measured, sufficiently high and localized to dynamically localize the tracking coil in real time with a tracking stability factor of > 95% (frame to frame hit rate). The multi slice alternation scheme was changed in real time. Slice orientation was changed using the graphical slice-positioning tool (GSP) of the scanners users interface with support of options of the context menus. The option to copy a slice position or set an orthogonal slice was proved to be important to quickly find useful slice orientations. The catheters coil provided a well-localized signal and undesired signals, for example from the micro coaxial cable, were either not present or sufficiently suppressed.

Discussion

Projection signals used in catheter tracking can be contaminated by signals coupled from other imaging coils such as external surface coils or through the use of inappropriate tracking coil geometries. Some coil geometries, such as the dipole antenna [7], have a signal profile that is well localized in two dimensions but extends over many centimeters along the catheter axis. This effect can also occur for other coil geometries and is generally an indication for inadequately suppressed shield currents or poor decoupling. The tracking module can be made more robust by applying more sophisticated data acquisition schemes and data analysis. Currently, each gradient echo is analyzed using a simple peak finding algorithm. The integration of the interactive sequence into the standard software environment is important to provide typical scanner functions. However, a dedicated user interface is needed for interventional MRI. The multi slice sequence presented here can easily be used with the generalized interactive user interface proposed in [8].

References

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