Real-time Scan Plane Selection with a Novel Hand-held Device for Needle Guidance

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Introduction: In image-guided needle insertion, the location of the needle, surrounding anatomy, and target must be visualized in real time with sufficient spatial and temporal resolution and with appropriate contrast. Many techniques have been developed which track the location of an interventional device attached to the needle and update imaging planes to follow the device. However, flexing of the needle can cause misregistration between the device and the needle tip. A largely unexplored alternative in MRI is to allow the interventionalist to control the slice position independent of the needle position. This control can be realized by manipulating a simple hand-held device with active tracking markers. Using these markers, the location and orientation of the device can be determined in real-time and used to prescribe scan plane locations. Combining this device with the previously developed wireless MRI receiver technology[1] allows the system to perform seamlessly in the already crowded magnet bore. This work presents preliminary results of a real-time slice positioning system using a hand-held wireless tracking device.

Theory: To achieve slice position updates, the location and orientation of the wireless device must be determined in real-time. Previous work in interventional MRI has shown that the position of active and passive tracking devices (e.g. microcoils) can be determined in real-time with the collection of several projections with varying orientations and maximum magnitude reconstruction[2,3]. The locations of three markers are required to determine the plane of the device. In this work, each marker is connected to its own receiver channel enabling localization of all markers with three orthogonal projections and a computationally simple reconstruction.

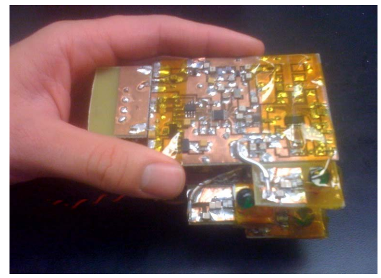

Figure 1: Picture of the wireless tracking device without housing. The green spheres (8mm diameter) are the signal sources and sit on top of the multi-turn butterfly coils.

Methods: All experiments were performed on a Siemens 1.5T short and wide bore system (Espree). ***Wireless Tracking Device:*** Each active tracking marker consists of a multi-turn butterfly coil with a localized signal source. The coils were tuned, matched, and amplified with low noise preamplifiers. A wireless prototype of the three channel tracking device is shown in Figure 1. The signals from the three channels are transmitted simultaneously using amplitude modulation encoding[1] and are received outside the magnet bore. ***Slice Positioning Algorithm:*** The markers were imaged with a standard FLASH sequence that was modified to collect three orthogonal tracking projections prior to each slice acquisition. Tracking projections were acquired with large field of view (400 mm) and base resolution (256), yielding a tracking resolution of 1.56 mm. The marker spatial coordinates were determined from the Fourier transformation and maximum magnitude reconstruction. Acquiring the projections, processing feedback, and updating the slice location took approximately 25 ms.

Results and Discussion: Using the device location and orientation as the slice center and scan plane, a real-time FLASH (128x128, 300x300mm, TE=2.3ms, TR=4.9ms FA=30^o) was acquired using a resolution phantom. Figure 2 shows several frames from this acquisition and corresponding device orientation. To demonstrate agreement between the device orientation and scan plane, signal from the tracking device was included in reconstruction, which reveals all three tracking markers in the imaging plane. Signal from the phantom was collected with a sixteen channel ventral cardiac array. Figure 3 shows the device defining the scan plane of a real-time FLASH sequence (96x128, 300x300mm, TE=5.2ms, TR=9.4ms FA=25^o) with a human volunteer. The slice center was chosen to be 150mm distal (half field of view) from the device center in order to place the body in the middle of the field of view. Utilizing the device's spatial information is flexible and customizable, in that once the location and orientation of the device is determined, this information may be utilized in many different ways. Operation of the tracking device is limited to inside homogenous region of the magnet so the projection acquisition encodes the tracking location accurately.

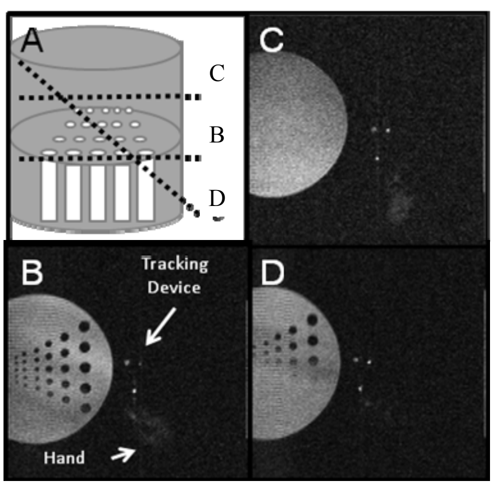

Figure 2: (A) The tracking device selects three image planes demonstrating both translational and rotational orientation shifting. (B-D) Images show signal from tracking markers, which demonstrates agreement between the device orientation and scan plane. Signal from the hand holding the device is also seen in the images.

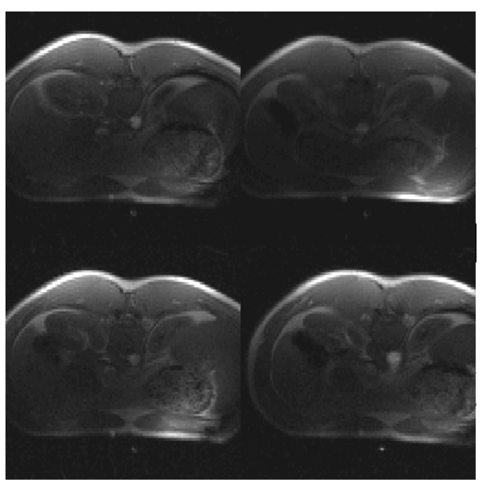

Figure 3: Real-time FLASH images of a human volunteer where the tracking device defines the slice position. Signal was collected with a 32 channel cardiac array, but only using 24 channels (right posterior group not utilized). The array was slightly sensitive to the tracking device's signal sources, which alias into the bottom of the field of view.

Conclusion: A real-time scan plane selection technique using a novel hand-held tracking device is presented. This allows a physician to easily and directly control the image plane in a needle guidance procedure without interruption.

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References:

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