A System for Real-time Interventional MR Imaging and Tracking of Devices

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Introduction:

A system for real-time tracking of interventional devices in an MR scanner was developed. This tracking system uses a point source tracking technique (1) where small receive coils are built into interventional devices (e.g. catheters). The signal is detected using the same physical principles as MR Imaging and MR tracked points are inherently registered with reference and roadmap MR images. Advanced features such as real-time control of the scanner, thermal difference imaging, EKG triggered cine loops, and device visualization enables effective MR Guided interventional procedures.

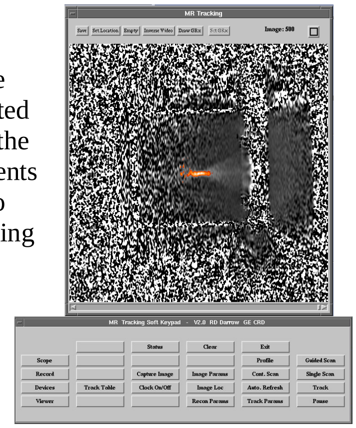

Figure 1

Methods:

The system described here uses a spatially non-selective RF pulse that excites all nuclear spins within the volume of the RF excitation coil. The MR signal is detected by a small receive coil having limited spatial sensitivity, and embedded in an invasive device. The signal is detected in the presence of magnetic field gradients and Fourier transformed to compute the location of the coil along the axis of the applied gradient. The entire process is repeated with orthogonal gradients to obtain a set of three-dimensional coordinates of the coil. A switch is added to the scanner to allow rapid transition between imaging coils and device tracking coils. Unlike traditional imaging where a set of images is first prescribed and then acquired, image acquisition with the MR Tracking system is controlled in real-time. In order to meet the requirement of real-time interaction and control, the system employs a single pulse sequence that performs all the imaging, tracking and profiling functions. The operator needs to download this sequence to the scanner only once during a session.

Discussion:

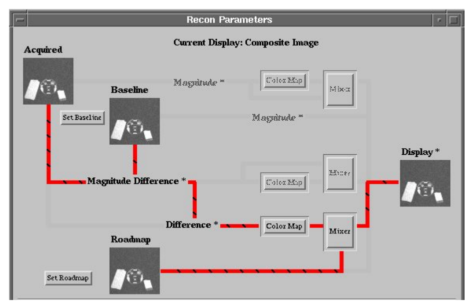

Figure 2

The MR Tracking system offers a number of advanced features that facilitate MR guided interventions. The system can perform real-time multi-planar tracking on up to 5 images, or on any previously acquired image in the main display (Figure 1). The Graphic Recon Control panel (Figure 2) is used to define and modify the reconstruction algorithm. Magnitude, phase, real, and imaginary data can be displayed. Magnitude, phase and complex difference images (with respect to a selected baseline image) can also be displayed to provide thermal (as shown in Figure 1) and/or perfusion weighted images.

A spline interpolation algorithm has been implemented to enhance visualization of flexible devices such as catheters and guidewires. The system allows for up to eight receivers on up to eight different devices. Figure 3 demonstrates active tracking of a 5-coil device in a pig.

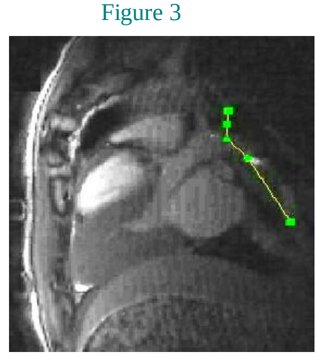
Figure 3


Figure 4

Real time tracking can also be performed on 3D MRA MIP images. Figure 4 shows one frame from a 3D acquisition where a 3-coil device is tracked and the coil locations are linked using a cubic spline (pink), while the projection angle of the roadmap image is continuously changed. Cine images of a beating heart can also be used as a roadmap. These cine loops are synchronized to the patient's EKG signal, to permit real-time tracking using a cine movie as a temporally correct roadmap. The system also offers a graphic prescription tool allowing real-time selection of non-oblique planes.

Conclusions:

Active MR tracking of point source catheters provides real-time visualization of vascular devices in an MR scanner. Tracking by itself, however, is not sufficient for most interventions. Features such as advanced device visualization, thermal imaging, EKG triggered cine loops and multi-plane tracking make the system presented here well-suited for MR Guided interventional vascular procedures.

Reference:

1.Dumoulin CL, Souza SP, Darrow RD (1993) Magn Reson Med 29:411-15