Integrated Real-time MRI User-Interface

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Introduction: For interactive real-time MR, it is important to efficiently and intuitively prescribe scan planes and obtain visual feedback on the prescription. This is necessary for applications such as basic 3D navigation (e.g. for coronary artery localization) and guidance of interventions. A variety of approaches to implementing real-time scan plane navigation and visualization have been tried previously. 2D images and 3D mice provide some of the required prescription flexibility but suffer from limited, non-intuitive representations of the input and output data. It is likely that no universal “best” method exists for efficiently and intuitively manipulating real-time MRI. We address this issue in the current work through the creation of a general framework for integrated real-time prescription and visualization to allow any number of interfaces to work together to provide a customizable scanning environment.

Implementation: Conceptually, the framework presented here is an extension of the “virtual machine” concept [1] to the user-interface component of a real-time scanning system. Central to the idea of a flexible real-time interface is the identification of the critical information needed to for scan plane prescription and visualization. This consists of the essential geometry (rotation/translation matrix and physical scaling – i.e. the field-of-view) and timing (elapsed time, cardiac and respiratory phase) information. To control the distribution of this information to an arbitrary number of visualization/prescription applications, a socket-based client-server geometry sharing application was written. This server application can receive or distribute the critical scan plane information to any other client application. In our specific application we have developed a flexible real-time scanning interface (Figure 1) on a 1.5T scanner (GE CV/i) that can communicate with the server application and control a real-time acquisition on the scanner. This scanning interface contains many of the traditional real-time user-interface elements including a 2D image display of the real-time data reconstructed using a sliding window reconstruction [2], simple translational and rotational sliders/selections and graphical line prescriptions for scan-plane prescription. The interface itself was designed using a modular, object-oriented philosophy, making it easily adaptable to new features, data pathways or integration with a variety of MR systems (e.g. integrated motion tracking [3], physiologic monitoring [4] or real-time velocimetry [5]). With the real-time acquisition, control interface, and geometry sharing server application in place, additional applications can be easily integrated for improved scan plane navigation and visualization. Using this approach we integrated a 4D cardiac visualization tool [6] that places the current real-time image within the context of a 3D data set for easier cognition of the spatial location (Figure 2). In addition we integrated a 6 degree-of-freedom robot arm [7] that provides a true physical 3D representation of the scan position that is registered to the subject’s position to overcome 2D computer monitor visualization limitations (Figure 3).

Results: An initial implementation of this combined scanning and visualization system was completed and tested for imaging healthy subjects. A multi-phase, volumetric FIESTA data set was first acquired and loaded as the reference in the 4D visualization tool. Interactive real-time scanning was initiated and the current scan plane was continually updated on the real-time scanning interface, the 4D visualization tool, and the robotic arm based on prescription information from any of the applications. Currently the interactive real-time interface operates on the local scanner computer and the 4D visualization tool and robot driver software executes on a separate computer running a Real-Time Linux operating system which illustrates the flexibility of not only integrating different applications but ones running on different systems.

Discussion: The integrated information from all 3 systems provides a much more intuitive and efficient system for real-time scanning. Through the near simultaneous coordination and input/output capabilities of all 3 systems there is significant flexibility for an individual user to navigate in an efficient manner. Additional applications that provide alternate methods of prescription and scan plane visualization can easily be integrated.

Conclusions: A framework for integrating visualization and scan prescription tools -- both physical and software – was developed for interactive real-time MRI scanning to enhance the efficiency and intuitiveness of scan plane localization. This system could be applied wherever fast intuitive localization or tracking in 3D or 4D is required.

References: 1. Santos J. et al., *ISMRM,* 2002. **2.** Kerr A. et al., *MRM*, 1997. **3.** Sussman M. et al., *IEEE TMI*, 2003. **4.** Stainsby J. et al., *ISMRM,* 2001. **5.** Macgowan C. et al., *ISMRM,* 2002. **6.** Radau, P. et al., *ISMRM,* 2004. **7.** Yi, D. et al., *ISMRM*, 2004.

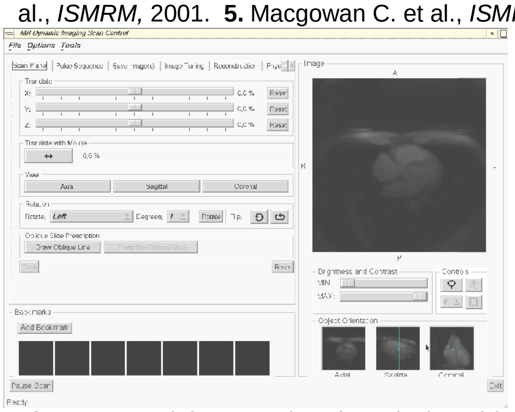

Figure 1: Real-time user interface designed for controlling the scan plane using sliders and graphical line prescriptions.

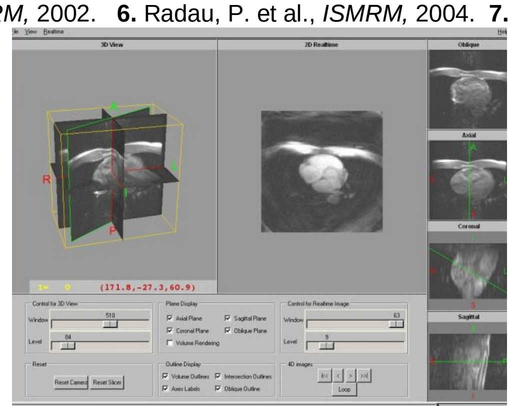

Figure 2: Snapshot of the 4D visualization tool showing prior 4D data synchronized spatially and by phase to the current 2D real-time image. Aids in placing the current 2D real-time image within a 3D/4D context.

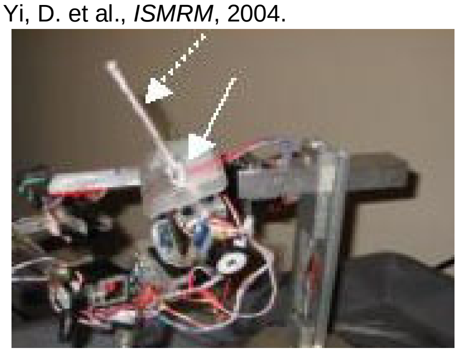

Figure 3: 6DOF robotic arm showing representative scan plane (solid line) and normal vector (dotted line) that provides a physical 3D representation of the scan plane for easier navigation/prescription.