Interactive MR imaging using parallel acquisition and parallel reconstruction

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Background

Image-guided therapy is an emerging field where MRI has shown to provide significant added value, as an intra-operative imaging modality, in many applications. While open MRI systems have not lived up to their expected potential, an increasing number of procedures are being performed using conventional closed bore systems. Some procedures use an in-out paradigm, like neurosurgery, while concomitant imaging and intervention is possible for a wide range of catheter-based procedures, high-intensity focused ultrasound (HIFU) procedures, and robot-aided procedures. We are motivated by catheter-based cardiac procedures. Real-time scanning and interactive prescription of the scan plane based on the location and orientation of the catheter is essential for these procedures. In order to minimize interactive delay (time from prescription to the image is displayed [1]), fast imaging and fast reconstruction have to be employed. This abstract describes a novel system for interactive MR imaging were the scan plane can be prescribed by any 5 or 6 degree-of-freedom device and both the image acquisition and computation of the reconstructed image are performed using parallelization. This work was supported by NIH grant U41-RR019703.

Methods

The modularized concept of interactive scan-plan prescription and parallel acquisition and reconstruction is depicted in Figure 1. The tracked device can be a treatment delivery device such as a catheter, or user interface device such as a 3D mouse. The system uses the tracker information both for visualization and for scan plane prescription. Real-time variables are being computed and sent to the pulse-sequence continuously. The system was implemented on a GE Excite 14.x system, but interfaces to other systems can be integrated in this modularized approach. Parallel acquisition was performed using an 8-channel coil and a steady state free-precession pulse sequence (FIESTA) with a 3.8x acceleration factor. 34 phase lines were acquired to reconstruct a 128x128 image. The TR was 3ms. Phase encode line sampling density was exponentially weighted, with a small number of low-frequency lines acquired for self-reference coil sensitivity estimation. The reconstruction was performed using a fast, regularized implementation of the SPACERIP reconstruction algorithm [2]. This algorithm is highly parallelizable, and was modified to run in an arbitrary number of concomitant threads. The reconstruction was performed on an a80 VizNode with 8 dualcore CPUs. The reconstructed images were displayed using an open-source software framework called the Slicer Image Guided Navigator (SIGN) [3]. This software allows additional control over the scan plane, and can combine real-time navigation with navigation based on 3D data sets.

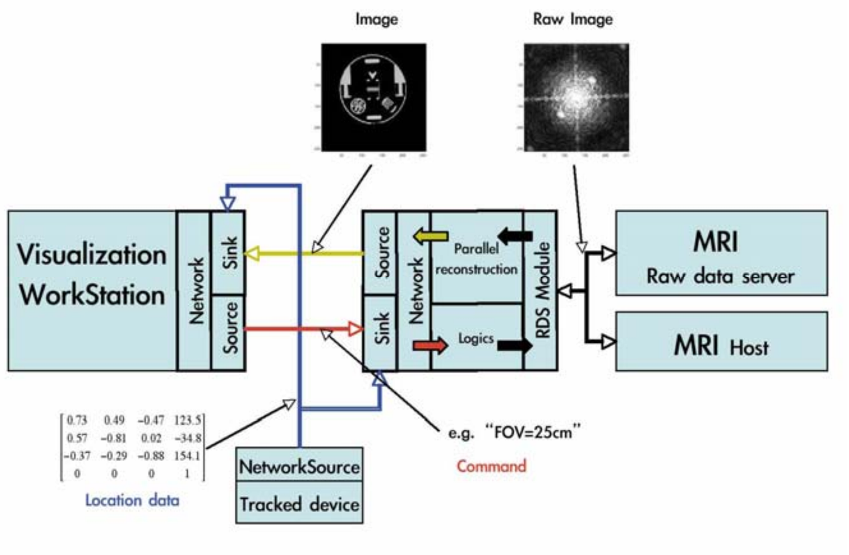

Figure 1: Schematic of interactive system. Tracking information is transmitted over a network connection to a module that can modify scan parameters in real time, as well as to a visualization workstation. This workstation can also control other scan parameters through a command interface. The k-space data is provided through a raw data server, and parallel processing is employed to reconstruct the image and transfer the resulting image for display in the visualization workstation.

Results and Discussion

With the imaging parameters as described above we could achieve an acquisition frame rate of 9 frames per second. By utilizing 2 dual core CPUs we were able to reduce the reconstruction time to 250ms. The target reconstruction time is 100ms as reconstruction needs to be faster than acquisition to maintain throughput. We are confident that we can archive this through optimization of memory usage and parallelization of the self-referenced coil sensitivity estimation. We observed that 40% of the reconstruction time was spent calculating coil sensitivity profiles. The coil sensitivity estimation approach [4] is based on a small number of central k-space lines, and if these are acquired first in the pulse sequence, the processing of these profiles can be performed while the rest of k-space is acquired. In conclusion, the interactive system that was developed can provide interactive control and display during real-time scanning at interactive speed.

References

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