ECG triggered MRI-guided navigation for cardiac interventions

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Problem

MRI-guided cardiac interventions have gained significant interest over the past decade. MRI provides the potential advantage of intra-operative anatomical imaging for the purpose of targeting, monitoring and control of the treatment. Several groups are currently working on enabling MRI-guided catheter based cardiac interventions (1-2). MRI can be used to target the therapy in cases where anatomical foci (such as myocardial scars) coincide with the electrophysiological foci. MRI has the potential to monitor the acute effect of tissue ablation as well and post-operative control. MRI can also be used for device tracking, using image based tracking, MR tracking or electro magnetic (EM) tracking.

Current approaches for cardiac MRI-guidance are either to use pre-operative datasets or real-time imaging. The purpose of this study was to enable concomitant navigation on 3D cardiac cine loops as well as real-time imaging using ECG triggering for accurate temporal registration and synchronization.

Methods

A software navigation system was implemented comprising the following main components: The core visualization application, an ECG acquisition and analysis system and a MRI-scanner software interface.

Interfacing with the MRI-scanner, in order to interactively control real-time scan plane orientation and location as well as access real-time images, was implemented through a networked abstraction layer, hiding vendor specific implementation details from the core application. The concrete implementation was done on a General Electric 12.x Excite platform.

The ECG acquisition system was implemented by connecting the patient intra-operative ECG leads to a PC through a National Instruments USB data acquisition unit. The ECG signal analysis included real time detection of the QRS complex as well as the heart rate (figure 1). An event was dispatched to the visualization system immediately following QRS detection including information about current heart rate.

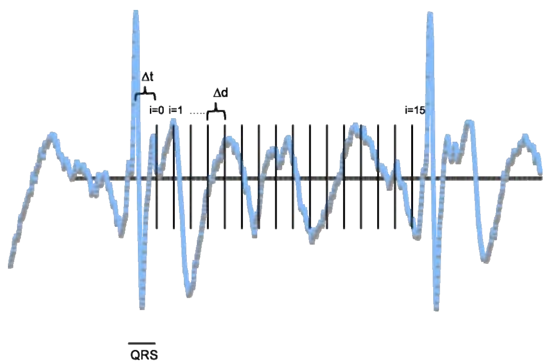

Figure 1: ECG signal, illustrating QRS complex, trigger delay (Δt) and delay (Δd) between each time point (i) in the multi-phase MRI volume.

The visualization system is able to visualize ECG-gated MRI volume cine loops in three orthogonal cross sections as well as using a volume rendering engine. At the same time real-time images can be displayed in the 3D view and annotated with tracked devices such as catheters. The real-time 2D images are spatially and temporarily registered with the 3D roadmap. Tracking information from devices (such as catheters) can also be used for real-time prescription of scan plane location and orientation.

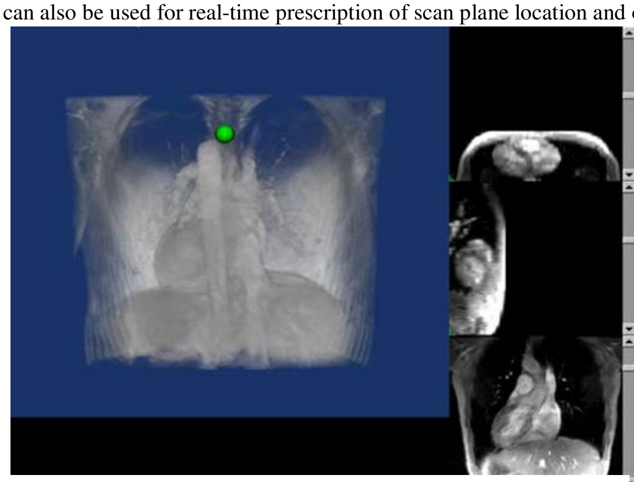

Figure 2: Volume rendering and 3-plane views of healthy volunteer. All displays can show time-registered cine-loops, and real-time images can be displayed in 3D and/or 2D views (real-time image not shown in figure for simplicity).

Results

The navigation screen from the visualization application is shown in figure 2. The dynamic nature of the application cannot be appreciated from the static figure. QRS detection was accomplished looking at 10 samples at a time, when sampling at 1000Hz, this gave a 10ms analysis interval. This resulted in a 10ms delay between QRS detection and retrieval of triggering signal for the visualization. The delay corresponded to the trigger-delay used in the ECG-gated MRI acquisition. The combined display allowed for gross orientation (3D view), detailed navigation (high-res 2D roadmaps) and verification (real-time 2D scan), and can potentially simplify navigation to complex anatomical structures such as pulmonary veins or contrast enhancing myocardial scars.

Conclusion

Cardiac navigation using MRI is feasible, and can be used in conjunction with real-time MRI for localization verification and assessment of real-time intervention. Navigation on cine-loops is not always desirable, however the presented approach can easily be modified to allow single-phase navigation.

References

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