Four-dimensional Visualization System for Real-time Scan Plane and Catheter Navigation

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Introduction In real-time MRI, a critical issue is the selection of the position and orientation of the 2D scan plane so that it is efficiently centred upon the regions of interest. This navigation is usually impaired by the difficulty in relating a 2D scan plane to the 4D (3D + time) beating heart. A software visualization system is presented that synchronizes the real-time images to a 4D prior image of the heart, and facilitates scan plane and catheter navigation.

Design Criteria The design has the following aspects: 1) A 3D global spatial context is provided to compensate for the limitations of assessing orientation from 2D images. 2) The reference volume has a temporal dimension that is synchronized to the real-time images to improve accuracy throughout the cycle. 3) The reference volume is high-resolution to improve navigation to small structures (e.g. coronaries) and precise targeting, and compensate for relatively low-resolution of real-time images. 4) The catheter is displayed with high temporal and spatial resolution to depict the instantaneous position relative to the target.

Methods The visualization system was developed and demonstrated on a 2GHz Intel PC with Linux OS and low-cost 3D graphics card (Nvidia GeForce4). This prototype was implemented with Python, TkInter graphical user interface, and the VTK library (1).

Implementation Prior to real-time scanning, a relatively high-resolution 4D prior volume is acquired from the patient to serve as a navigation guide during scanning. The prior volume is shown as 3 orthogonal, intersecting cut-planes (tri-planar display, Fig. 1). An independently colored volume rendering may be overlaid, and cine tools utilized to review the cardiac cycle. The tri-planar display can be rotated, zoomed and the plane depths adjusted during real-time scanning. The visualization system continuously updates the real-time image shown and simultaneously illustrates its location within the tri-planar display as an oblique plane to provide a context for the 2D image in the 3D prior volume. The 3D prior volume's phase is also updated to display the nearest available to match the current real-time image. User comprehension of scan plane orientation is enhanced by 3 reference images (axial, coronal, sagittal) and their respective intersection lines with the oblique plane. The response delay in this implementation of the visualization system is 96 ms (3D) and 171 ms (4D), including update of tri-planar display, oblique plane, real-time image and reference planes. An interventional catheter is visualized as a 3D surface rendered tube within the tri-planar display (Fig. 2), utilizing simulated active catheter coil position information (2) interpolated by a 3rd-degree spline. Catheter intersections with the reference images are represented as red (tip) or yellow ovals. For interventions requiring precise catheter placement, a target is identified on the prior volume and the navigation progress is tracked by a catheter tip-to-target line. This ideal trajectory line is continuously updated with its current length throughout the real-time MR scan.

Conclusion Visualization software has been developed that enhances efficient and intuitive scan plane and catheter navigation. Future work will develop tools for planning and guidance along optimal catheter trajectories through sensitive structures to targets, with real-time distance and angular feedback.

References

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2. Dumoulin CL, Khan IJ, Darrow RD, Rossi CJ, Kamal V, Buyer CO, Sierocuk T, Inderbitzen M. Active MR-Tracking Catheters Employing a Large Number of Independent Tracking Coils. ISMRM 2003, Abstract 314.

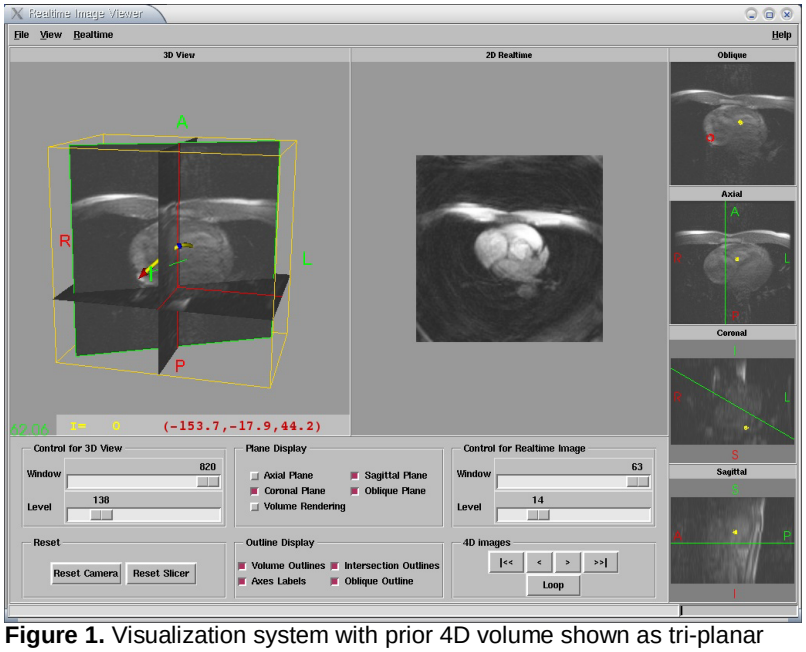
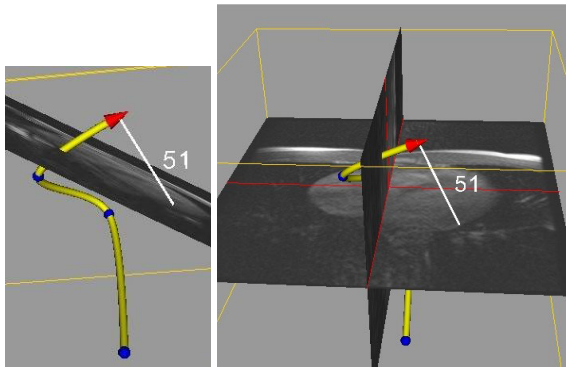


Figure 1. Visualization system with prior 4D volume shown as tri-planar display with oblique plane (left), current real-time image (centre), synchronized oblique plane (top right), and 3 references (bottom right).



A **B**

Figure 2. Catheter (yellow tube) is depicted with simulated location information from active catheter coils (blue). The catheter tip (red) guidance is enhanced by a line (white) connected to selected target, with distance in mm. Catheter and targeting line display can be updated in real-time during interventions. Fig. 2A shows the magnified catheter with oblique plane, and in Fig. 2B it is embedded in the tri-planar display.