Tracking Planar Orientations of Active Interventional Devices for Realtime Image Guided Procedures

S. Sathyanarayana[1], P. Aksit[2], A. Arepally[3], P. Karmarkar[3], M. Solaiyappan[3], E. Atalar[3,4]

[1]Electrical and Computer Engineering, Johns Hopkins University, Baltimore, Maryland, United States, [2]Global Applied Science Laboratory, GE Healthcare, Milwaukee, Wisconsin, United States, [3]Radiology, Johns Hopkins Medical Institutes, Baltimore, Maryland, United States, [4]Electrical and Computer Engineering, Bilkent University, Bilkent, Ankara, Turkey

Introduction: Tracking and visualization of interventional devices, such as catheters, is essential for guiding real-time MR procedures. Methods exist for tracking portions of the catheter using localizing RF coils [1], visualizing the entire length using active catheter antennas [2], and combining catheter views with anatomical images to aid in visualization [3]. Embedding microcoils on catheters, however, constrains their geometry and does not provide enough localizing information in procedures that require tracking of multiple points. Active antennas and viewing software help in visualizing the interventional device but there is no direct method to track the plane of the catheter and view its entire length in real-time without using localizing coils. We describe a method that determines the plane of the interventional device, using projection images, without the use of RF microcoils. Once identified, we can drive the scanner to be in-plane, orthogonal, or any orientation, with respect to the device. We demonstrate the method in an MR-guided creation of a mesocaval shunt performed *in-vivo* using an active intravascular needle system.

Methods: Real-time procedures often require various portions of the catheter plane to be tracked and visualized. For example, in the creation of the mesocaval shunt [4], a transvascular puncture is made from the inferior vena cava (IVC) to the hepatic portal vein (HPV) using an active needle with an angled tip (Fig 1). A successful puncture can be made when the plane of the angled tip ('catheter plane') coincides with the plane that passes through both the veins ('target plane'). The scan plane, thus, needs to be continuously updated to follow the plane of the angled tip. To accomplish this, we determine the catheter plane using two orthogonal projection images, an approach initially proposed by [5]. We drive the scanner to the catheter plane and calculate the plane's orientation with respect to an initially prescribed target plane (Fig 4), helping the physician orient the needle accurately for a successful puncture. In our implementation, we assume that: (a) the catheter is a one-dimensional wire like body; (b) its length along with the angled tip lies in one plane; and (c) there are no branches or loops in the catheter. All experiments were performed using a GE Signa 1.5T scanner. A modified Realtime User Interface provided orthogonal projection images and direct control of the scan pane. An active loopless catheter antenna in receive-only mode was used as the puncture needle. The catheter channel was combined with a four-channel cardiac array for images of the surrounding anatomy. A modified real-time SSFP sequence with real-time control of lipid suppression and inversion recovery was used for improved visualization of the catheter and the anatomy. The algorithm was implemented on a laptop PC connected to the scanner console by Ethernet (Fig 2).

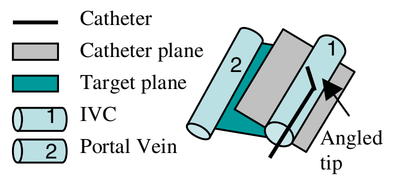

Fig 1: Need for plane tracking: catheter must be rotated to target plane for the puncture.

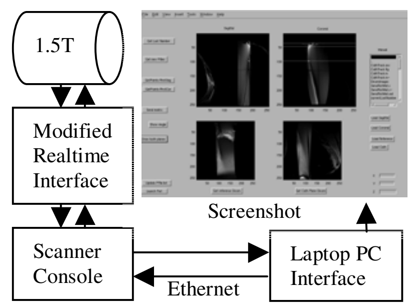

Fig 2: System architecture

Results: An *in-vivo* mesocaval shunt procedure in swine was guided using our method. The target plane, containing both the IVC and HPV, was initially prescribed and stored using a set of axial scout scans. During the procedure, modifications to the real-time user interface provided coronal and sagittal projection images of the catheter channel: the axial projection was not preferred since it can contain more difficult-to-resolve projection overlaps. The angled tip was located on the projection images (Fig 3) and the catheter plane was calculated in terms of a rotation matrix. The matrix was fed back to the scanner, adjusting it to the catheter plane. The angle between the current plane and the initially specified target plane was calculated (Fig 4), allowing the physician to rotate the catheter accordingly to make the puncture (Fig 5). Our current implementation requires user interaction to find the angled tip in the projection images. As a future enhancement, we propose the possible use of centerline detection algorithms to automate the process.

Conclusion: We have described a method for determining the orientation, and imaging the plane, of interventional devices without requiring localizing coils. The method was demonstrated in an *in-vivo* mesocaval shunt procedure. Previously, a trial-and-error navigation approach was used to orient the catheter, necessitating a more efficient approach. In this method, we directly determine the plane of the catheter using two projection images, thus minimizing the navigation time for a successful placement.

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References:

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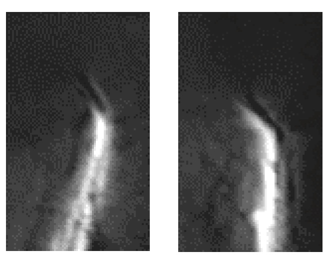

Fig 3: Sagittal and coronal projection images of the catheter channel from which the target plane is calculated.

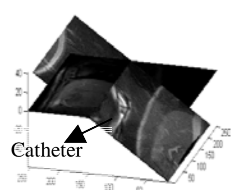

Fig 4: Catheter plane overlaid on target plane showing the required rotation.

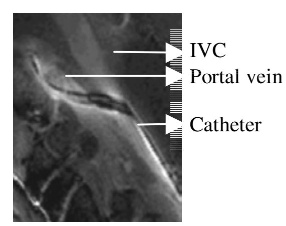

Fig 5: Correct orientation of catheter, aiding in puncture from IVC to portal vein