Electromagnetic Tracking of Endovascular Catheters

Computer Integrated Surgery II – Spring, 2023

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Introduction

We created a proof-of-concept system where surgeons can perform endovascular procedures using electromagnetic (EM) tracking of catheters. Specifically: we constructed **two catheter prototypes**; implemented **catheter tracking and path visualization module** in 3D Slicer; and developed **two different registration methods** to provide image guidance.

The goal of our solution is to **eliminate the need for x-ray fluoroscopy** in endovascular procedures **using EM tracking**.

Clinical Background

Brain aneurysms are bulges in blood vessels that occur primarily due to the thinning of artery walls. Left untreated, they can leak, rupture, and rapidly develop into life-threatening conditions.

The current standard of care involves guiding an endovascular catheter to the aneurysm site under x-ray fluoroscopy and CT angiogram. As a result, the surgical staff that routinely perform this procedure are at risk due to high levels of radiation exposure.

I. Hardware Prototype

Prototype Version 1

Directly place the EM 5-DOF sensor inside the catheter.

- Pros: Easy to implement
- Cons: No space for other tools inside the catheter

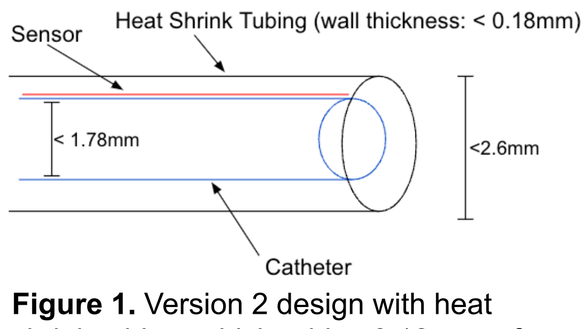
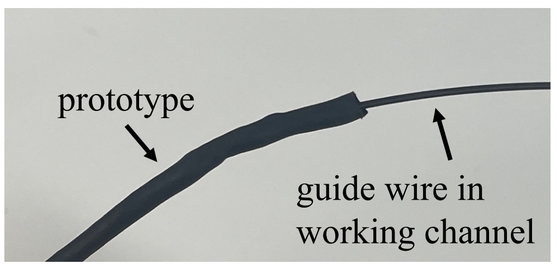
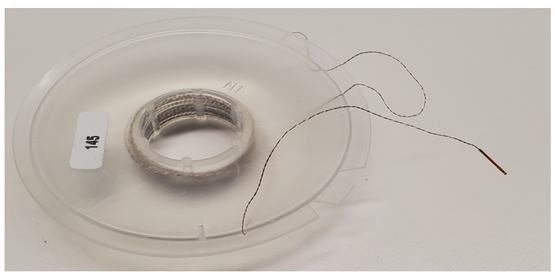


Figure 1. Version 2 design with heat shrink tubing, which adds ~0.18 mm of extra thickness.





Prototype Version 2

Place the EM 5-DOF sensor outside the catheter and use heat shrink tubing to secure it.

- Pros: Catheter working channel is open
- Cons: Increase catheter diameter

Figure 2. (top) Constructed prototype for version 1. The 5-DOF sensor is placed inside, which leaves no open working channel. (middle) Constructed prototype for version 2. The sensor is placed outside, thus leaving the working channel open. A guide wire is inserted within. (bottom) The 5-DOF coil sensor,[1] with a diameter of 0.45 mm.

II. Path Visualization

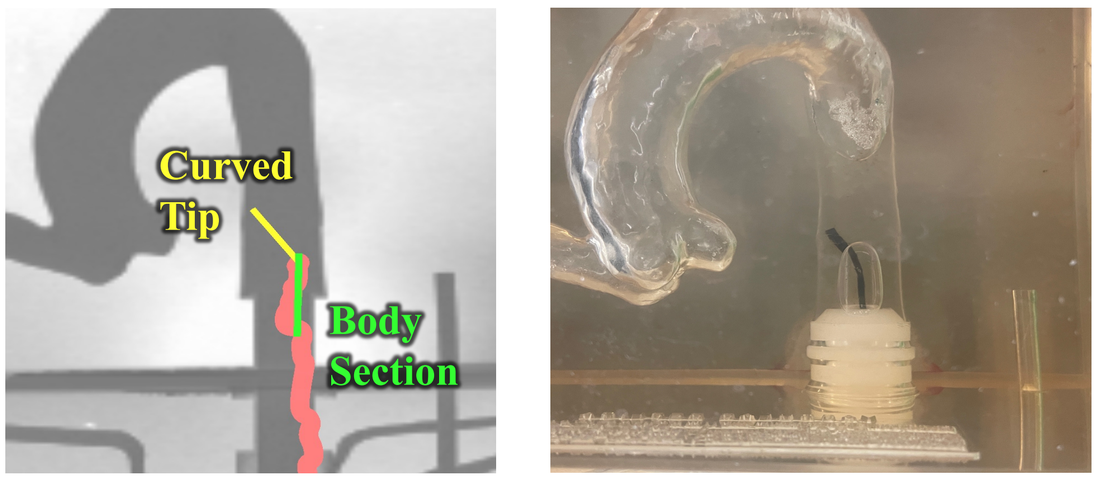


Figure 3. Side by side comparison of tracked catheter orientation and position in CT vs. actual catheter orientation and position in phantom.

Since the tip of the catheter is curved, and we only have one 5-DOF sensor attached, we developed an algorithm to estimate the position and orientation for both the curved tip and the body part of the catheter. We also have the option to color the path based on its curvature, which can be useful when trying to detect wrong turns during the actual surgery.

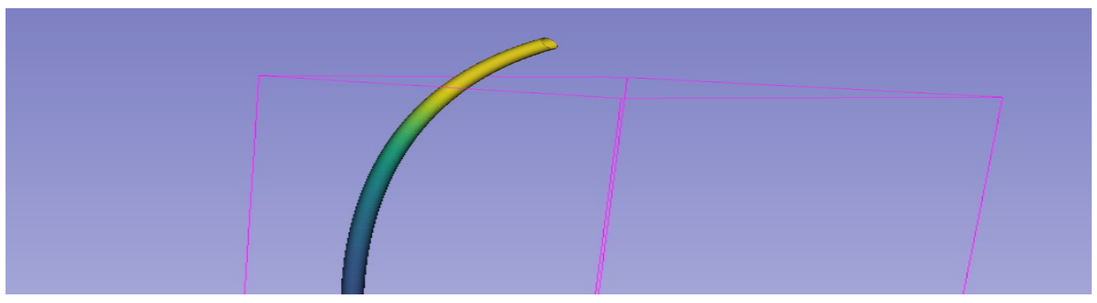


Figure 4. Color-coded path that denotes the motion curvature. The lighter the color is, the larger the curvature is.

III. EM Sensor – CT Registration

We have two registration workflows: the first one is point-based fiducial registration and the second one is a path-based approach.[2] In the GUI, we have one section showing the zoomed-in vision, one showing the 3D path, one showing the coronal plane, and one showing the sagittal plane.

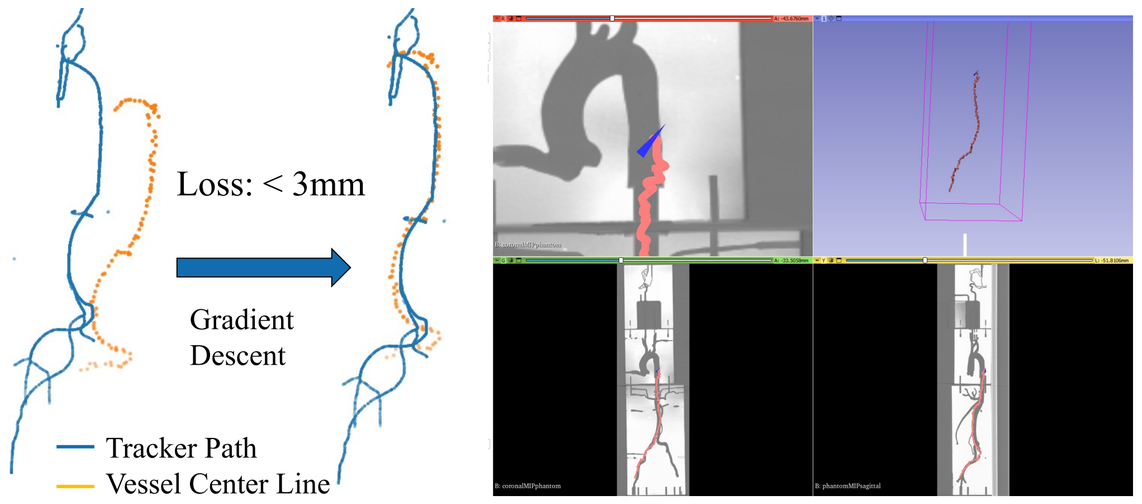


Figure 5. (left) The algorithm finds the transformation between the tracked path and the vessel center lines. (right) GUI after registration.

Conclusions and Future Work

We will be continuing into the summer, with a focus on evaluating our current system. We will improve on the current algorithm and visualization to provide a more effective guidance to the surgeon.

Lessons Learned

We spent quite a bit of time thinking about details at the beginning of our project. We realized that implementation can help organize our thoughts and bring new ideas. Our experience with 3D Slicer made us realize the importance of documentation.

Credits and Acknowledgements

Huilin: catheter prototyping, Fangjie: path visualization, Shanelle: image registration

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[1] “Aurora Sensors,” *NDI*. https://www.ndigital.com/electromagnetic-tracking-technology/aurora/aurora-sensors/ (accessed May 10, 2023).

[2] Lambert et al. “Electromagnetic tracking for registration and navigation in Endovascular Aneurysm Repair: A phantom study,” *European Journal of Vascular and Endovascular Surgery*, 43(6) 684–9, 2012.

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