



Electromagnetic Tracking of Endovascular Catheters

Department of Computer Science | Johns Hopkins University | Baltimore, MD

Team Introduction

❑ Group Member:

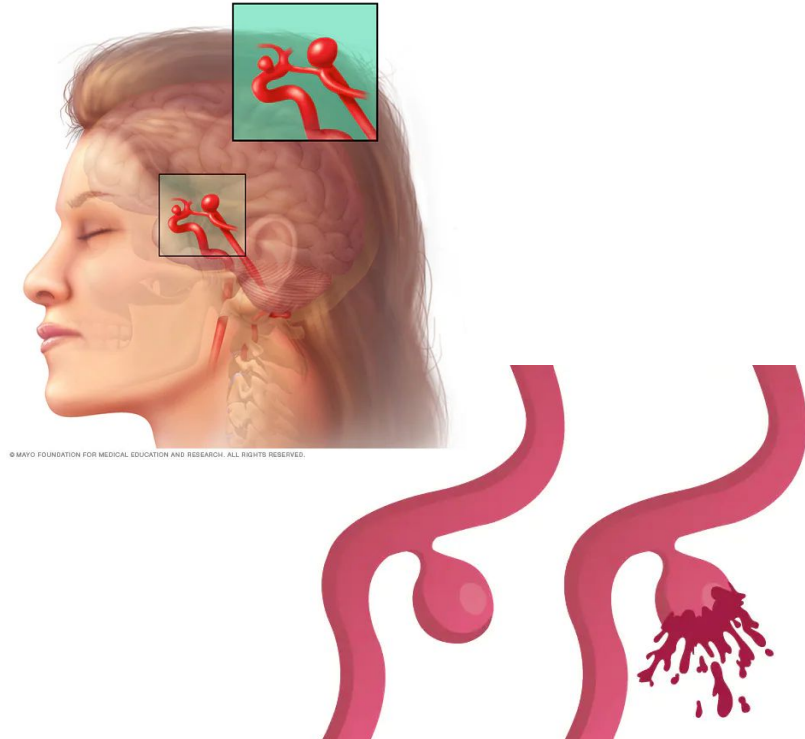
- Huilin (Lin) Xu, Senior EE&CS Undergrad
- Fangjie (FJ) Li, Senior BME&CS Undergrad
- Shanelle Cao, Senior ChemBE&CS Undergrad

❑ Mentors:

- Dr. Ali Uneri
- Dr. Fernando Gonzalez

Background: Brain Aneurysms

- ❑ Brain aneurysms are bulges in blood vessels in the brain due to thinning artery walls.
- ❑ If ruptured, can quickly develop into life-threatening situations
- ❑ 30,000 annual cases in the US, and 50% are fatal [1].



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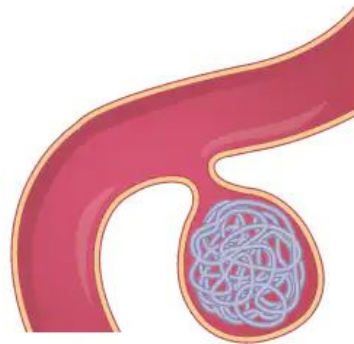
1. <https://www.bafound.org/about-brain-aneurysms/brain-aneurysm-basics/brain-aneurysm-statistics-and-facts/>

<https://www.mayoclinic.org/diseases-conditions/brain-aneurysm/symptoms-causes/syc-20361483>

Background: Current Treatments

Endovascular coiling

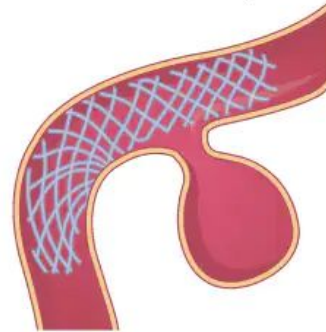
- Aneurysm is accessed by a catheter, inserted in an artery at the groin and guided to the brain.
- Soft platinum wire is fed through the catheter, coiling up inside the aneurysm.
- Causes blood to clot within the aneurysm, sealing it from the artery.



Sources: MayoClinic.org.

Flow diversion

- Aneurysm accessed by a catheter, inserted in an artery at the groin and guided to the brain.
- Metal mesh tube is placed in the artery, across the aneurysm.
- Blood flow is channeled through the mesh tube, away from the aneurysm.
- Clot forms within the aneurysm.



Catheter Path Properties

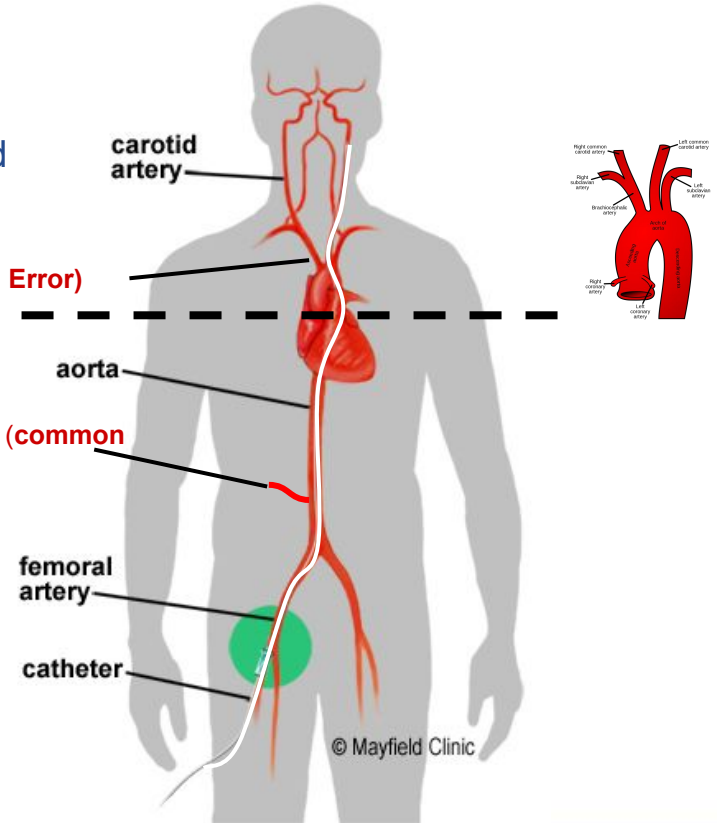
Carotid and Cerebral Artery

- Delicate vasculature (~mm diameter)
- High risk of path error
- Navigation relies on fluoroscopy with contrasting agent and pre-operation CT angiography

Femoral Artery and Aorta

- Relatively robust vessels (~cm diameter)
- Relatively straightforward path, 2 primary failure points
 - renal artery
 - junction arch
- Navigation relies on fluoroscopy, usually without contrasting agent

Arch of Heart (Common Error)



Problem Statement

- ❑ Endovascular navigation requires fluoroscopy to real-time track the position of the catheter

- ❑ Exposes both the patient and the surgeon to large amounts of radiation (hundreds of mGy)
 - Increased health risks such as cancer, cataracts, non-malignant skin damage, and impaired fertility. [1]

- ❑ We wish to eliminate the need of fluoroscopy through the use of electromagnetic tracking

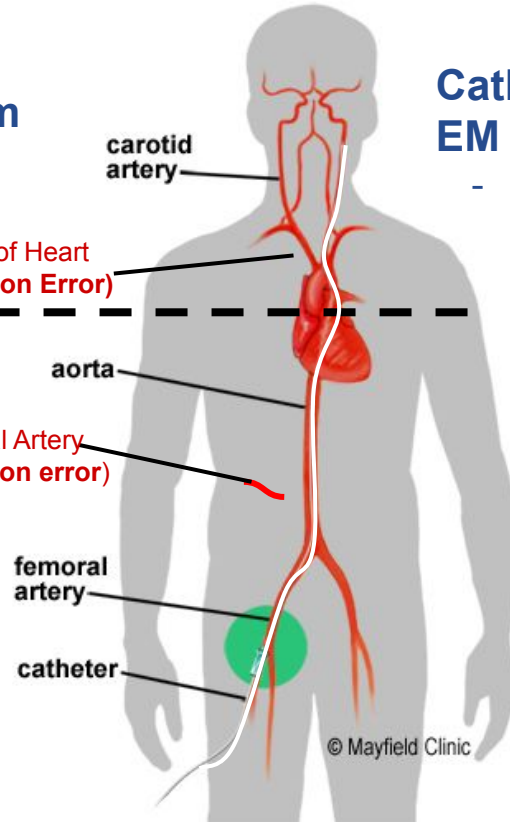
Proposed Approach with EM Tracking

Carotid and Cerebral Artery (Maximum Deliverable)

- Non-rigid registration of path to CTA

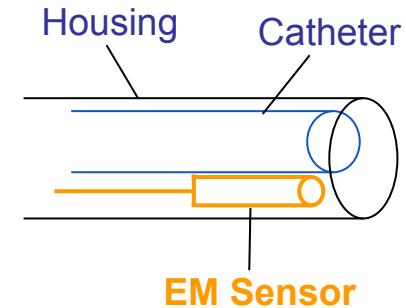
Femoral Artery and Aorta (Expected)

- Registration of path to a rough model
- Model: Non Patient specific coronal X-ray imagery
 - Registered to patient body



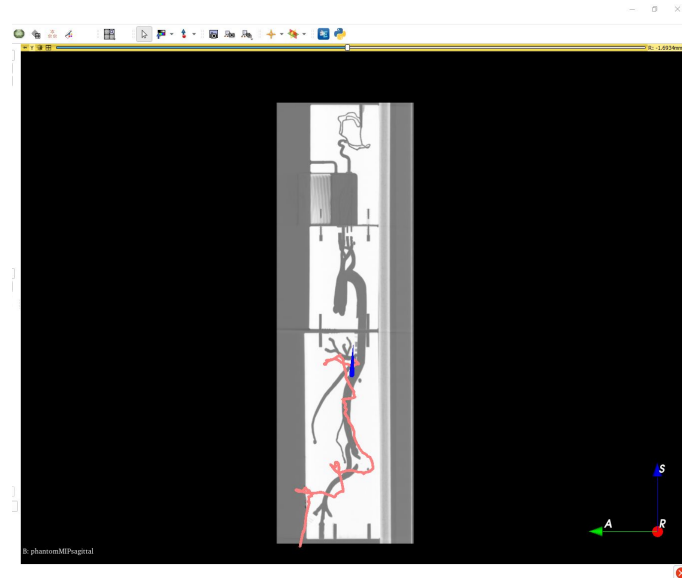
Catheter with Tip-embedded EM sensor (Minimum)

- The necessary hardware for tracking to occur.



Prior Work

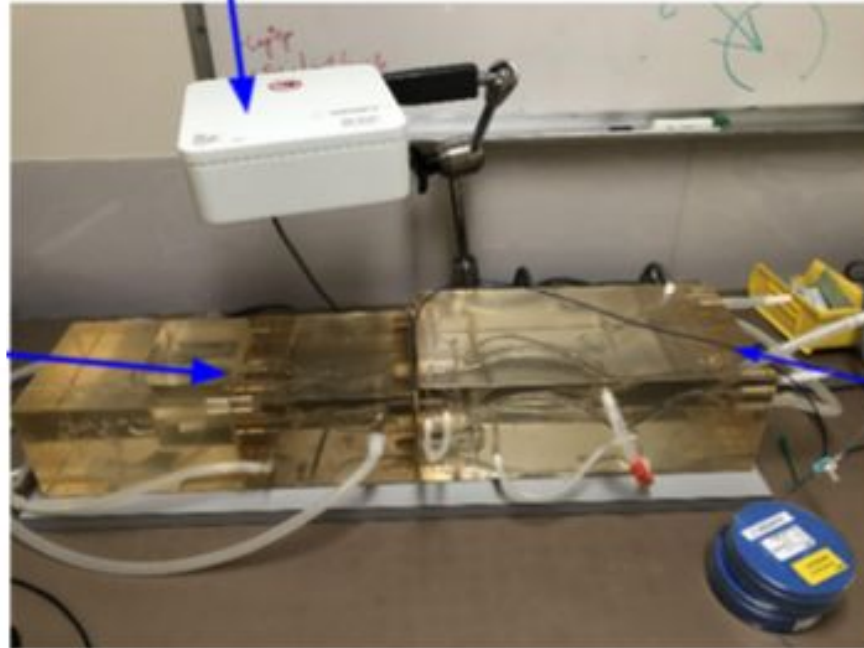
- ❑ Path Tracking based on EM sensor data
- ❑ Lack of mature registration algorithm and catheter prototype



Technical Approach: Setup



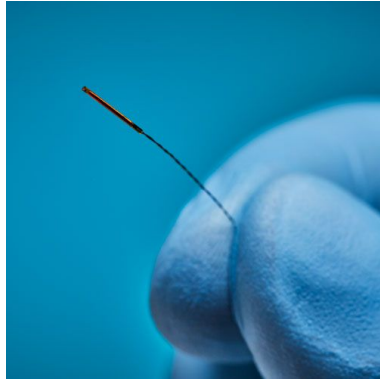
Aurora
Field Generator



Phantom

Catheter

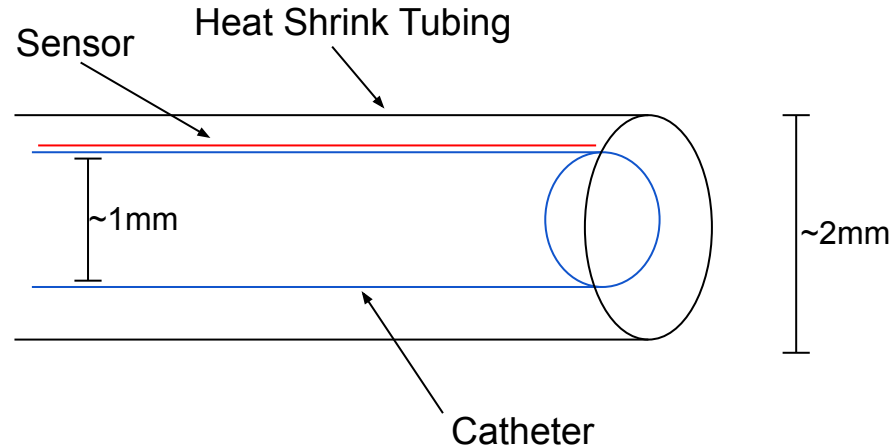
Technical Approach: Catheter



5-DOF Sensor ($\varnothing 0.45\text{mm}$)



middle cerebral artery (2.5-mm diameter)



Sensor wire will be enameld and hard glued on catheter.
Heat shrink tubing serves as extra protection.

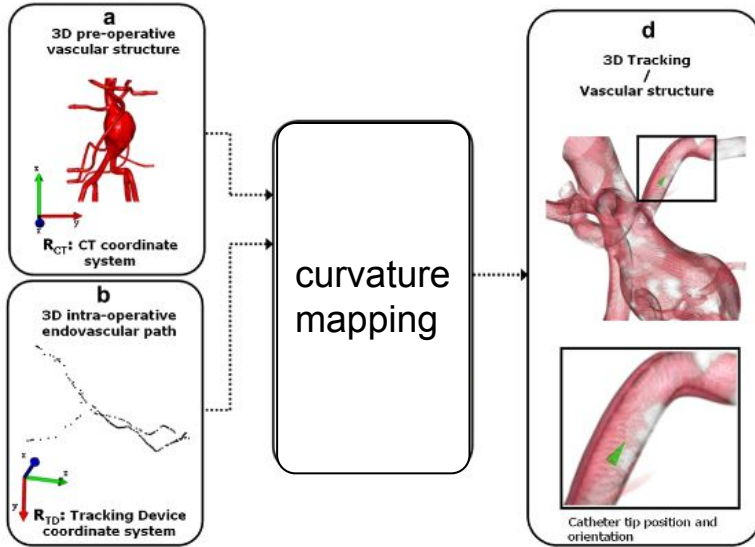
Nikoubashman, O., Nikoubashman, A., Büsen, M., & Wiesmann, M. (2017, December). *Necessary catheter diameters for mechanical thrombectomy with adapt*. AJNR. American journal of neuroradiology. Retrieved February 19, 2023, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7963740/>

Technical Approach: Rough Model Registration



1. Manually mark several fiducial points on rough model
2. Use catheter tip to perform points cloud registration

Technical Approach: CT Registration



1. Extract vessel centerlines to represent the essential shape
2. Perform non-rigid registration
- Coherent Point Drift



featured curve when
entering aortic arc

de Lambert, Albéric, et al. "Electromagnetic tracking for registration and navigation in endovascular aneurysm repair: a phantom study." *European Journal of Vascular and Endovascular Surgery* 43.6 (2012): 684-689.

Chi, Wenqiang, et al. "Learning-based endovascular navigation through the use of non-rigid registration for collaborative robotic catheterization." *International journal of computer assisted radiology and surgery* 13 (2018): 855-864.

Goals

Minimum Deliverable	Hardware prototype: A catheter prototype integrated with an EM sensor on tip, which can be used in phantom surgical studies. Evaluation Protocol: For evaluating the accuracy and robustness of EM catheter tracking.
Expected Deliverable	Software: tracking and visualization of the catheter on a rough model of the primary catheter path fitted to the patient's physique.
Maximum Deliverable	Software: Registered tracking of the catheter path on cerebral CT angiography.

Dependencies

Dependencies	Status	Follow Up	Contingency Plan	Deadline
Aurora EM Field Generator	Acquired	—		—
Aurora 5-DOF Sensor	Acquired	—	Purchase multiple	—
Preliminary Catheter Prototype (for early stage data collection)	Acquired	—		—
Prototyping Materials (wire insulating varnish and heat shrink tubing)	Unacquired	Will be ordered after discussing design with mentors		March 1st
Prototyping Tools (soldering station, heat gun, etc.)	Acquired	—		—
Main Body Artery Phantom	Acquired	—	Use backup phantom or DIY	—
Main Body Coarse Model	Acquired	Currently using phantom CT data; may switch to open X-ray dataset if available		
Brain Artery Phantom	Unacquired	Will discuss with mentors on availability	DIY w/ tubing & 3D printing	April 1st
Cerebral CTA Data	Unacquired	Will acquire data through online open sources		April 1st
Softwares (Computer with 3D Slicer, Plus server, Aurora driver, and path visualization module installed)	Acquired	—		—
Access to lab space and workshop	Acquired	—		—

Timeline

Process		February	March	April	May
Catheter Prototype	Design	█	█	█	
	Manufacturing Prototype		█	█	█
	Evaluation of the Prototype, in comparison to existing EM sensor			█	█
Tracking Algorithm within Model	Setup Existing Path Tracking System	█	█		
	Evaluation Existing Path Tracking Result, Identify Room for Improvement		█	█	
	Path Visualization Documentation for Modification of Path Visualization and Coarse Model Registration			█	█
	Path Visualization Algorithm Improvement			█	█
	Evaluation of the improved path tracking Algorithm				█
	Coarse Model Identification and Acquiring (Generic CT or single X-ray)		█	█	
	Path-to-Coarse-Model Registration Algorithm (Point Cloud)			█	█
	Evaluation of the Registration + Tracking Model				█
Registered Tracking on Brain CT	CTA data Identification and Acquiring			█	█
	Non-rigid Path Registration Algorithm for Brain CT (Coherent Point Drift)			█	█
	Acquiring Cerebral Artery Phantom			█	█
	Evaluation of the CTA Registration Model				█
UI Interface Design				█	█
Project Report and Presentation					█

Role Distribution

- ❑ Huilin Xu:
 - Hardware Prototyping
 - CT Registration

- ❑ Fangjie Li:
 - Test and Evaluation
 - Path Tracking Algorithm Improvement

- ❑ Shanelle Cao:
 - Rough Model Registration
 - CT Registration

Management

- ❑ Weekly meeting with Dr. Uneri and Dr. Gonzalez
 - Thursdays 3:30 PM

- ❑ Weekly group meeting
 - Tuesdays 3:30 PM

Reading List

Schulman, J., Ho, J., Lee, C., & Abbeel, P. (1970, January 1). *Learning from demonstrations through the use of non-rigid registration*. SpringerLink. Retrieved February 20, 2023, from https://link.springer.com/chapter/10.1007/978-3-319-28872-7_20

Nikoubashman, O., Nikoubashman, A., Büsen, M., & Wiesmann, M. (2017, December). Necessary catheter diameters for mechanical thrombectomy with adapt. AJNR. American journal of neuroradiology. Retrieved February 19, 2023, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7963740/>

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Ramadani, Ardit, et al. "Bioelectric Registration of Electromagnetic Tracking and Preoperative Volume Data." *arXiv preprint arXiv:2206.10616* (2022).