

Design and Control of a Continuum Wire Manipulator (CWM) for Minimally-Invasive Surgery *(Project 2)*

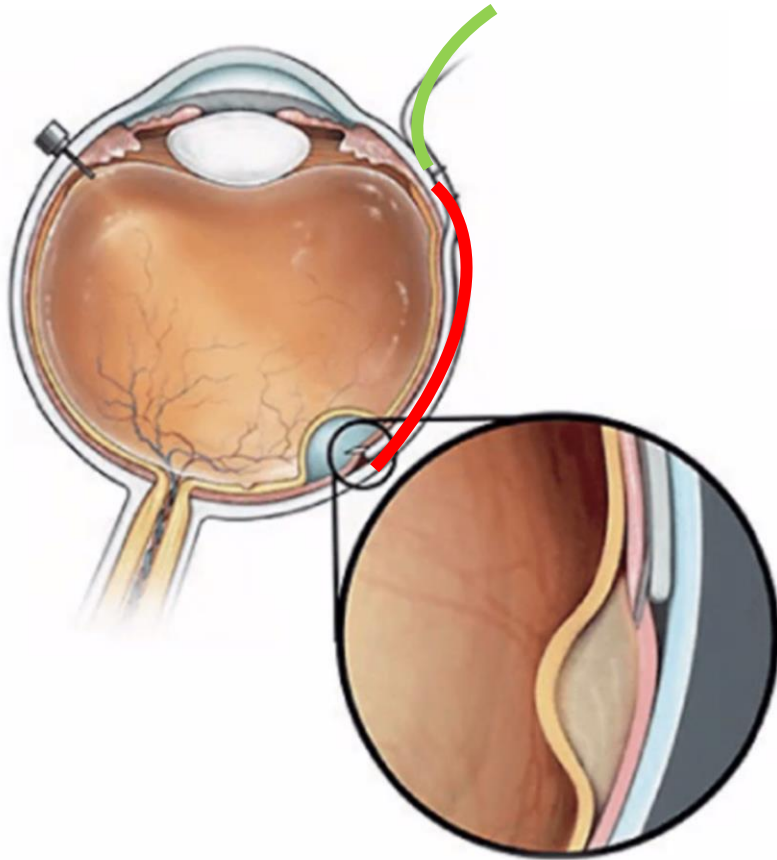
Mentor

David Usevitch, Ph.D.

Iulian Iordachita, Ph.D.

Student

Shuyuan Wang



- Problem
 - Retinal Degenerative Diseases affect **200M** people.
 - The **straightforward** needle would do harm on the eyeball and retinal.
- Solution
 - The continuum robot can find **minimal access** for safe subretinal delivery of gene therapy.
- CIS Deliverables
 - Design a mechanical **prototype** for the retinal robot.
 - Realize **motor control**.
 - Integrate with the Steady Hand Eye Robot (**SHER**).
 - Test **C- and S-shape** (tortuosity ability) in agar-gel.

- Peripheral Vascular Intervention (**PVI**)

Procedure to open blocked arteries and restore blood flow.

- COaxially Aligned STeerable (**COAST**) Robot

Guidewire robot to perform follow-the-leader motion

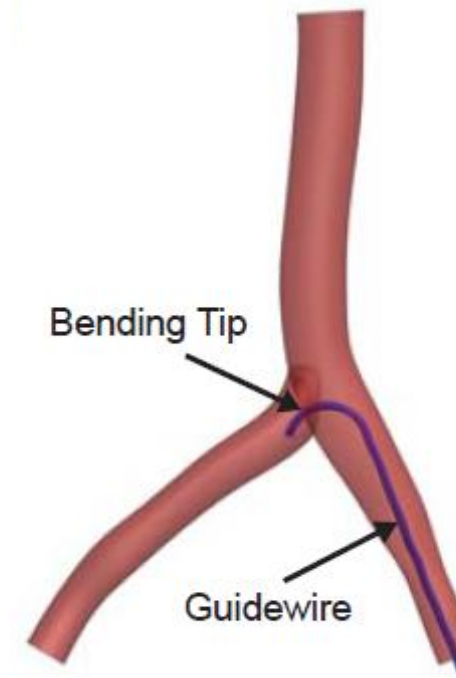
(steering capability at the end tip).

- **Tendon-Driven**

Use flexible wire (tendon) to transmit force and bend the region near the distal end.

- **Nitinol** Wires

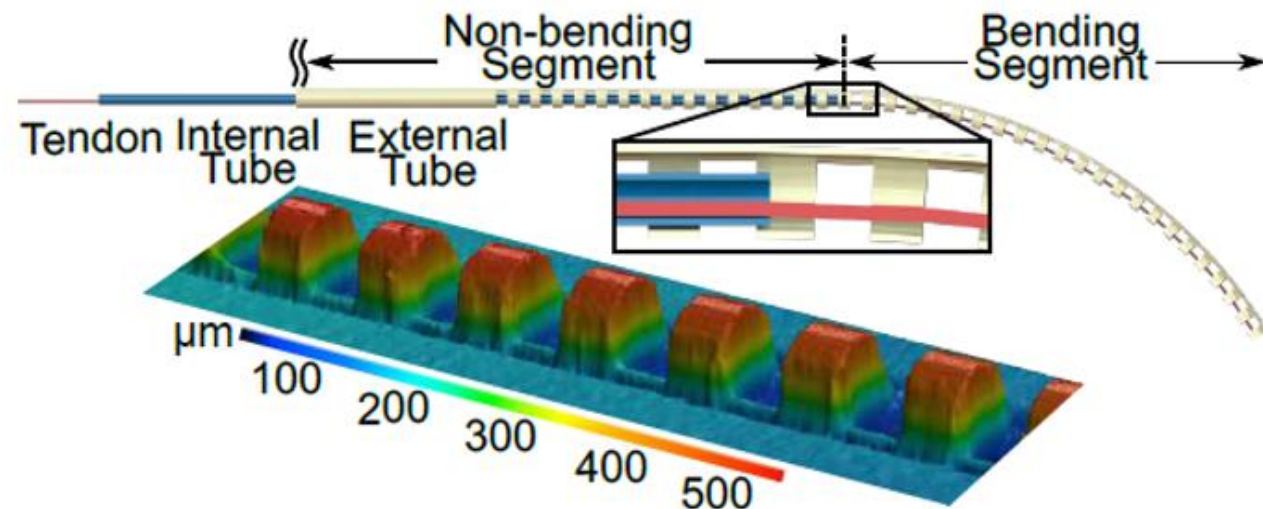
Super-elastic metal alloy of nickel and titanium, allowing repeated high curvature bends.



- **Title:** Design and Modeling of a Compact Advancement Mechanism for a Modified COAST Guidewire Robot
- **Authors:** Patrick Lis, Achraj Sarma, Grace Trimpey, Timothy A. Brumfiel, Ronghuai Qi, and Jaydev P. Desa
- **Conference:** 2022 IEEE International Conference on Robotics and Automation (ICRA)
- **Relevance:**
 - Flexible guidewire robot to go into the human body
 - Precise control of the robot shape to avoid puncture
 - Advancement mechanism to step in and out (advance and retract)

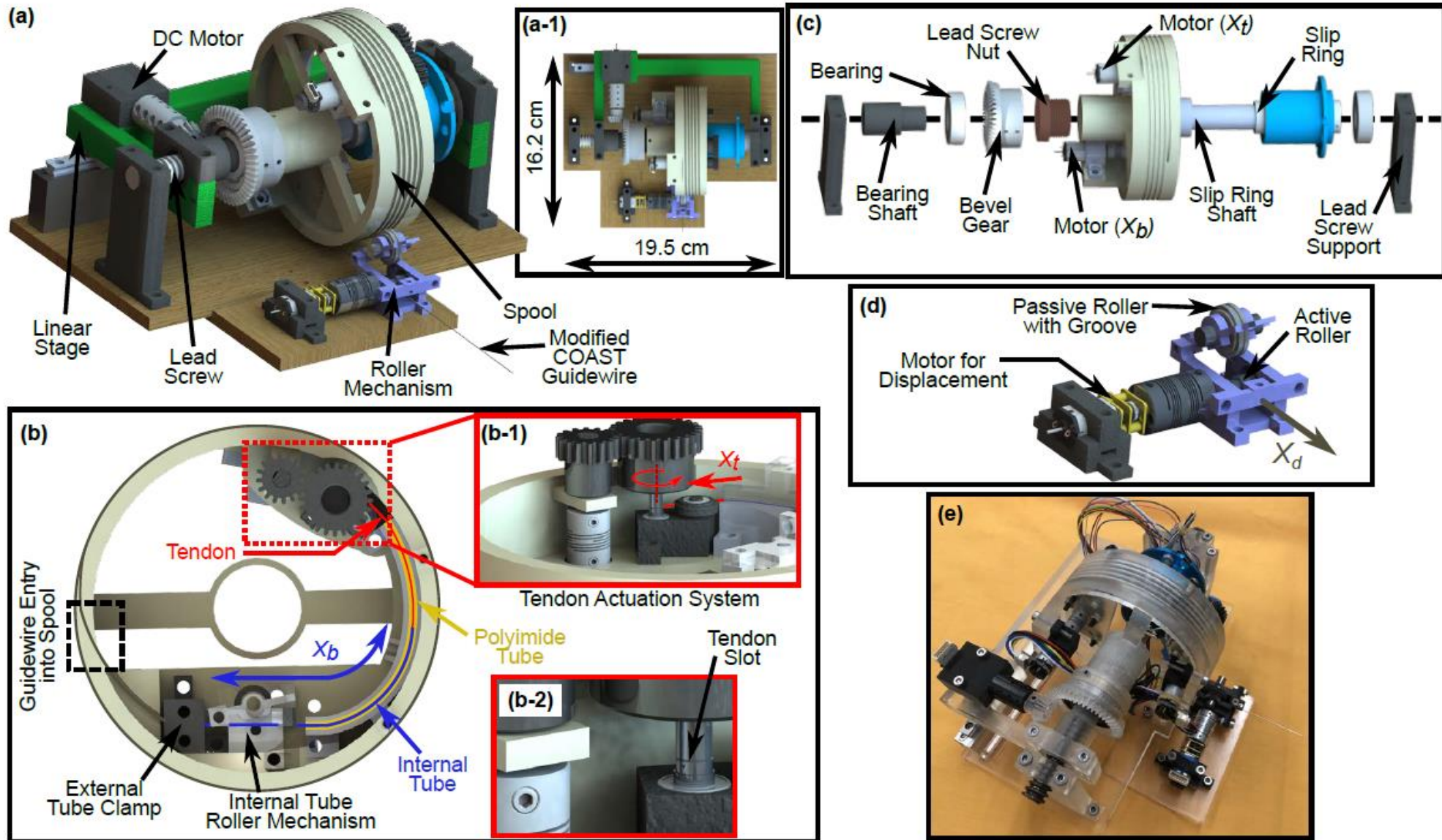
COAST Guidewire Robot

- **External tube** with rectangle notches
- **Internal tube** to add stiffness and adjust the bending segment length
- **Tendon** inside tubes
- Nitinol wire with diameter 0.076 mm
- Fixed at the distal tip of the external tube
- Can be actuated to achieve a desired curvature



$$\begin{bmatrix} X_t \\ X_b \\ X_d \end{bmatrix} = \begin{bmatrix} \text{Tendon Stroke} \\ \text{Bending Segment Length} \\ \text{Guidewire Displacement} \end{bmatrix}$$

Technical Approaches

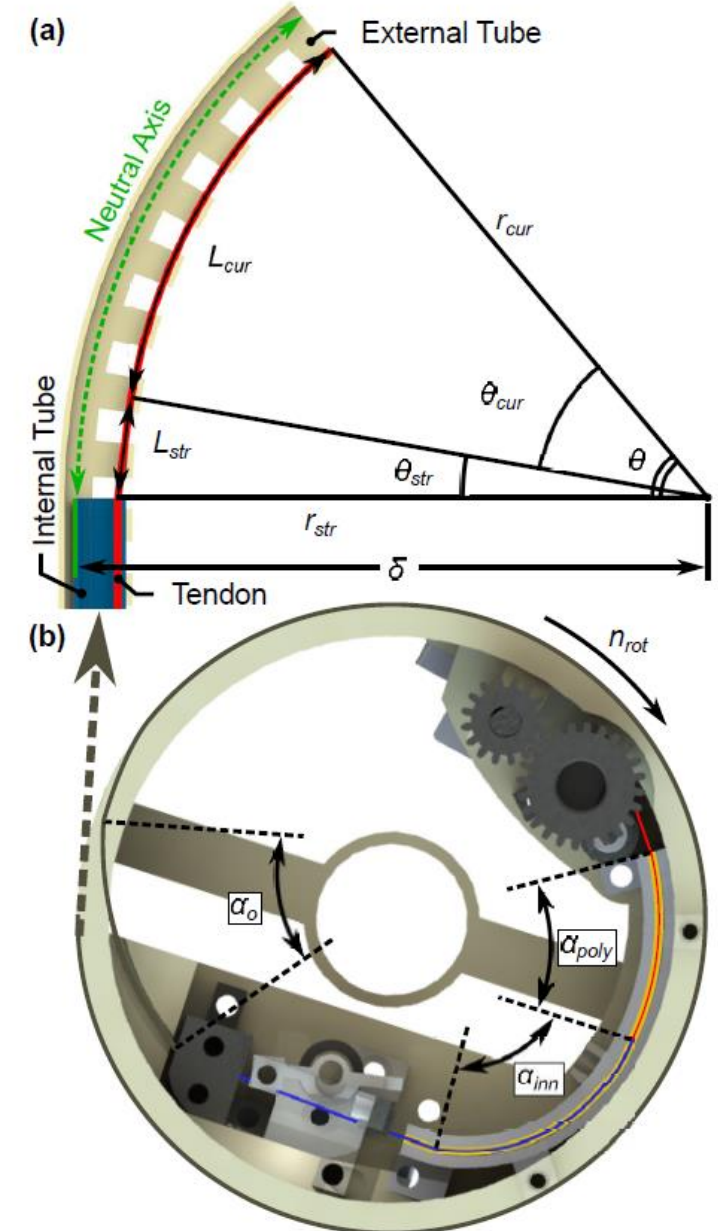


Lis, P., Sarma, A., Trimpe, G., Brumfiel, T. A., Qi, R., & Desai, J. P. (2022, May). Design and Modeling of a Compact Advancement Mechanism for a

Modified COAST Guidewire Robot. In 2022 International Conference on Robotics and Automation (ICRA) (pp. 1176-1182). IEEE.

Advancement Mechanism

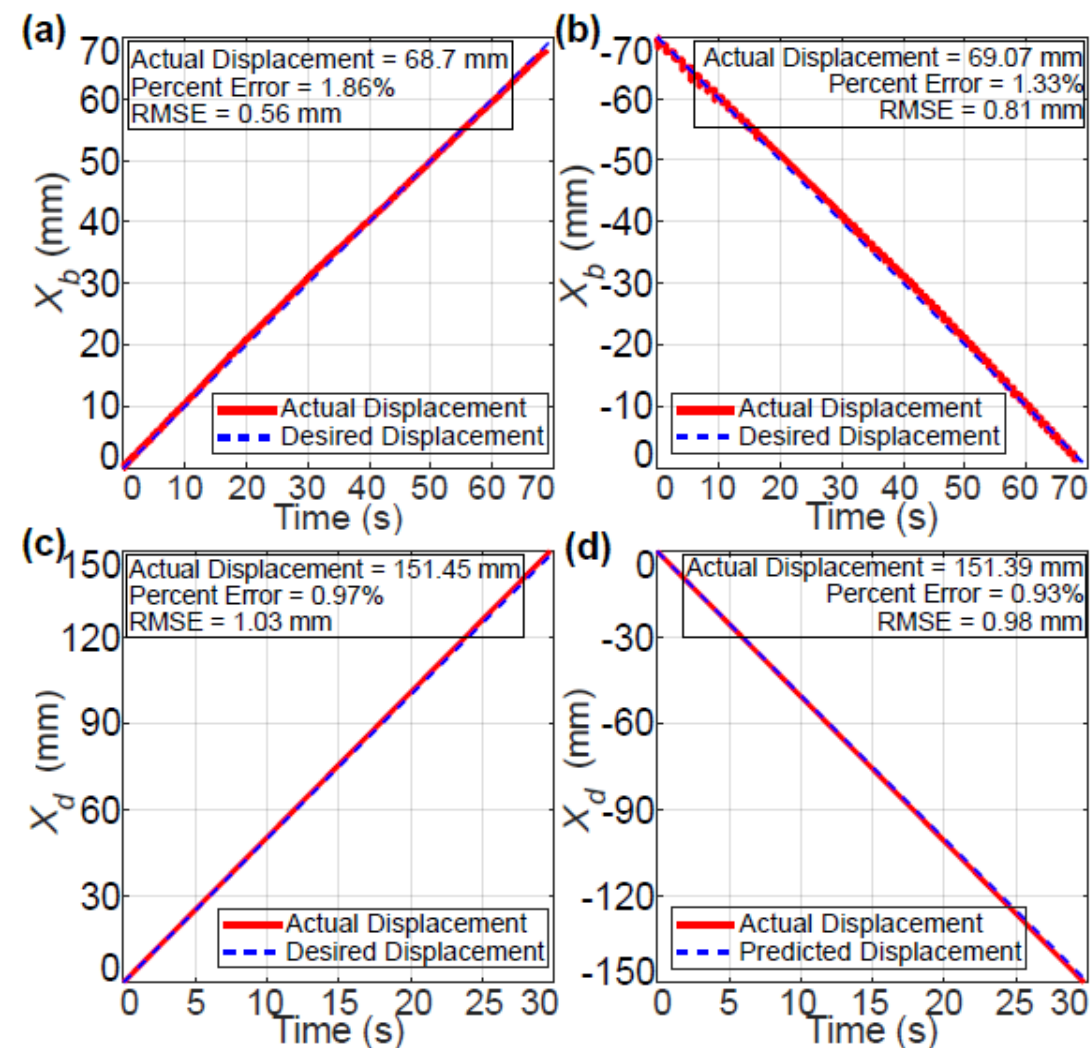
- **Spool, clamp, and roller mechanism**
 - Overlapped; bending & non-bending segment
 - Friction loss
- **Spur gears**
 - Tendon stroke; curvature
- **Independent motor system**
 - Guidewire displacement



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Evaluation of Actuation Mechanism

- Evaluate X_b (70 mm) and X_d (150 mm)
- Electromagnetic tracker to track the position
- Precise control both feeding and retracting
- Error less than 2% (solid VS dashed)

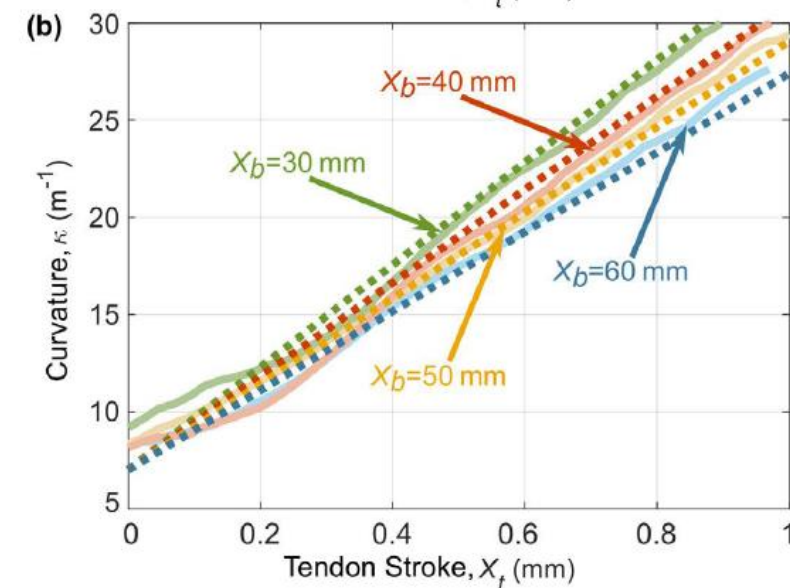
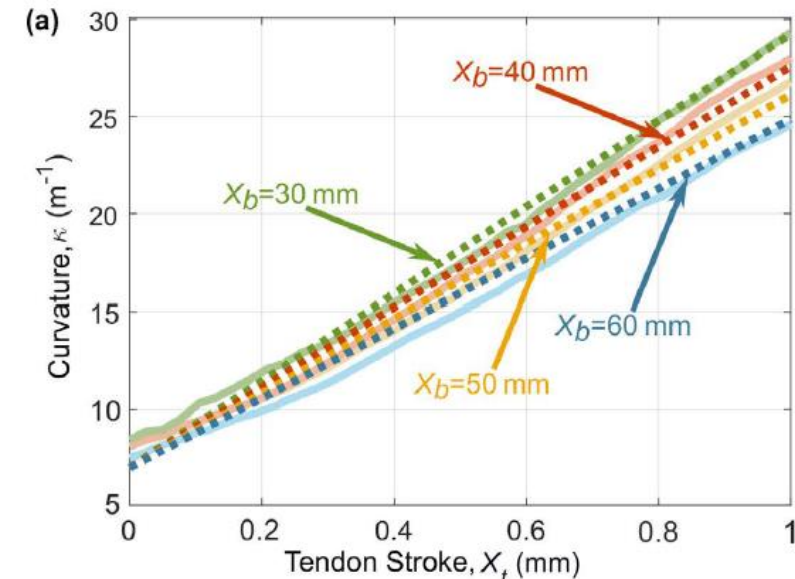


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Joint Model Validation

$$X_t = \Delta L_{mod}^{kin}(\kappa, X_b) + \mathcal{F} \frac{E(I_{out})L_{total}}{\Delta y_t E_t \pi r_t^2} \kappa$$

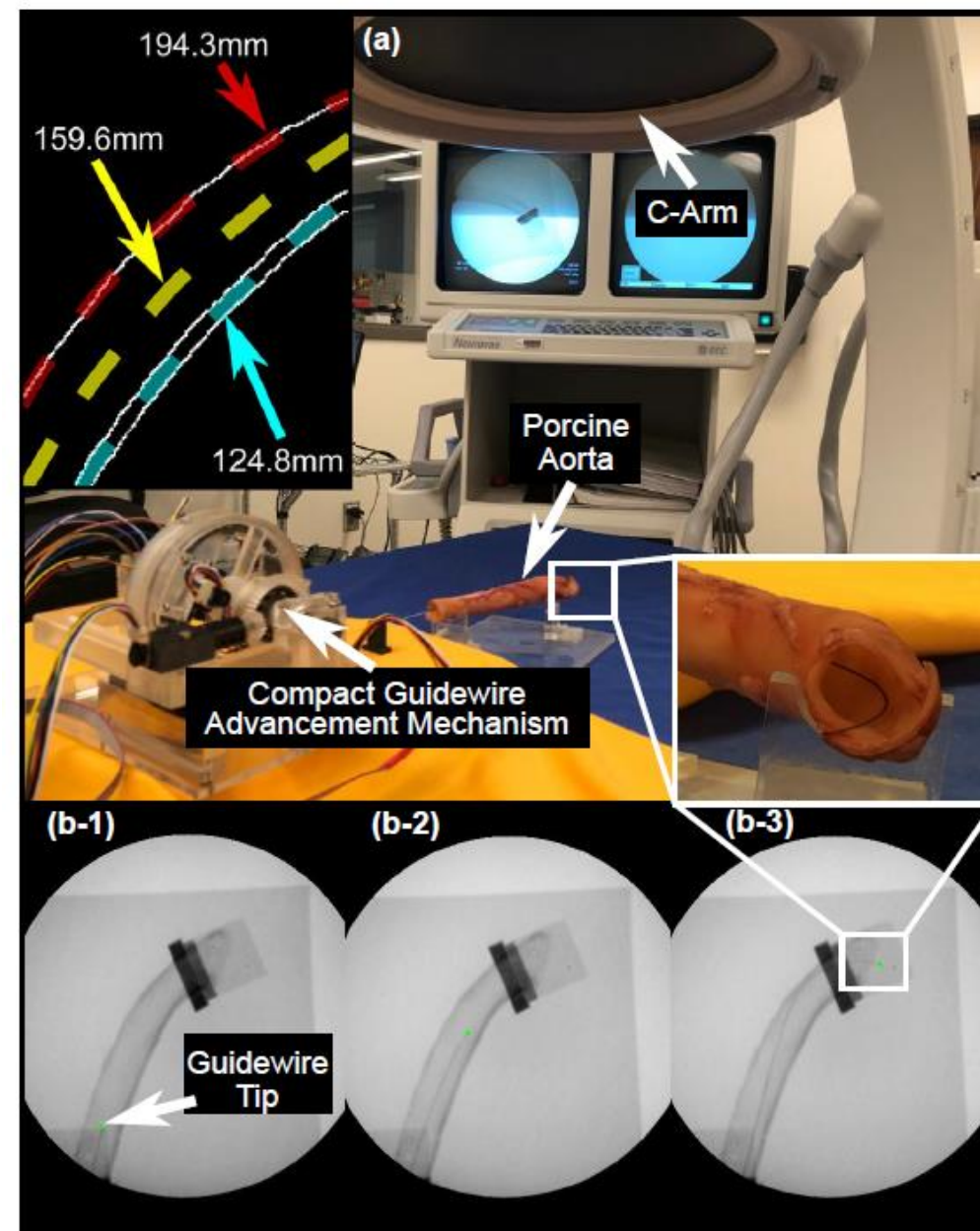
- Geometric stroke, Tendon Elongation, Friction Loss
- CMOS camera to estimate curvature
- Change in curvature with varying tendon stroke
- Experimental data (solid) fits the model (dashed)



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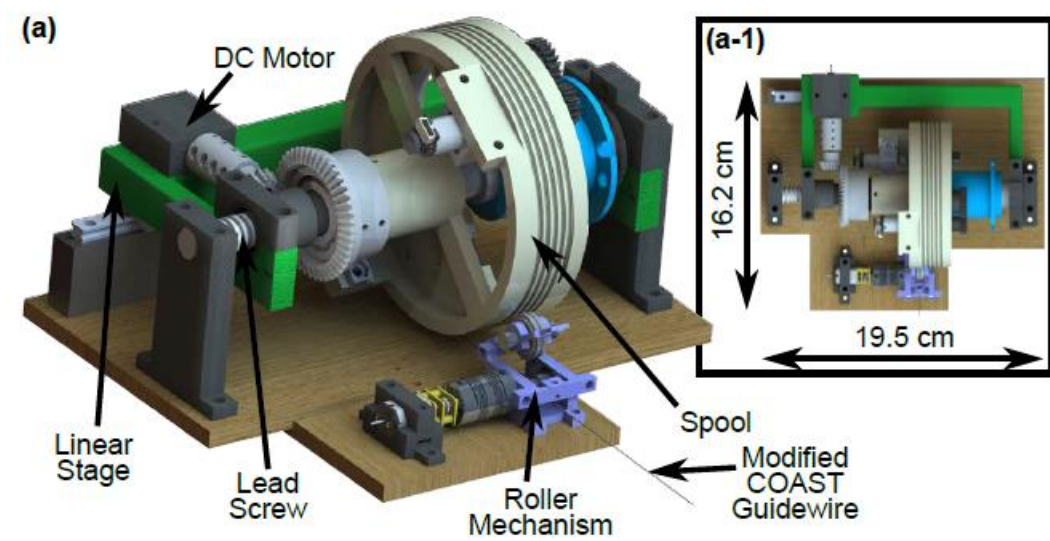
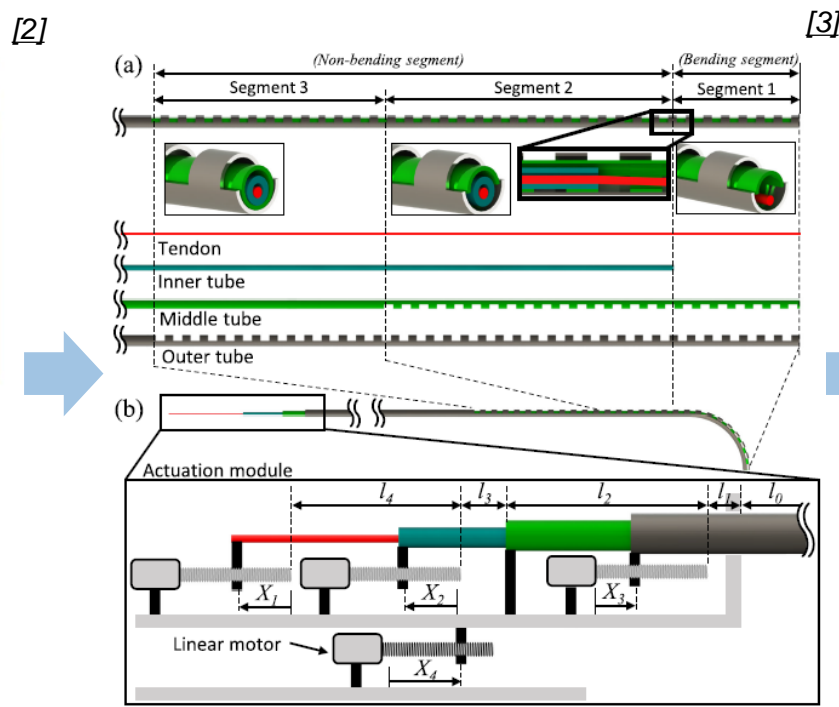
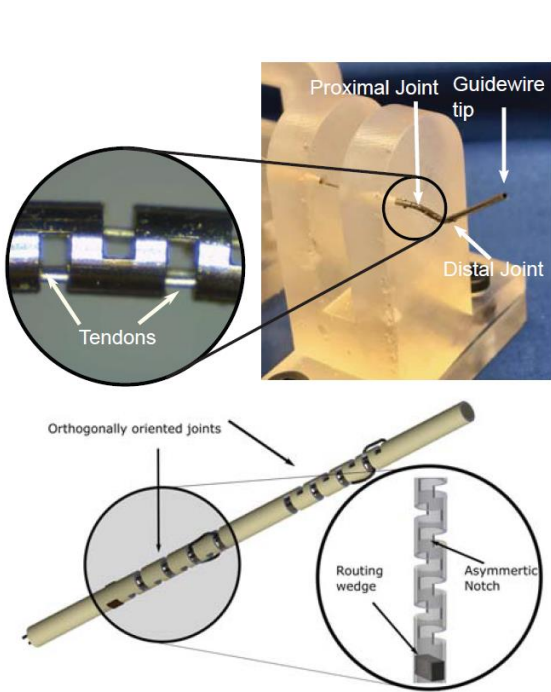
Demonstration In ex vivo Animal Vasculature

- Open-loop control to realize navigation
- Capture images, detect edges, identify the path
- Demonstration of guidewire moving at the beginning, middle, and end (green tip)



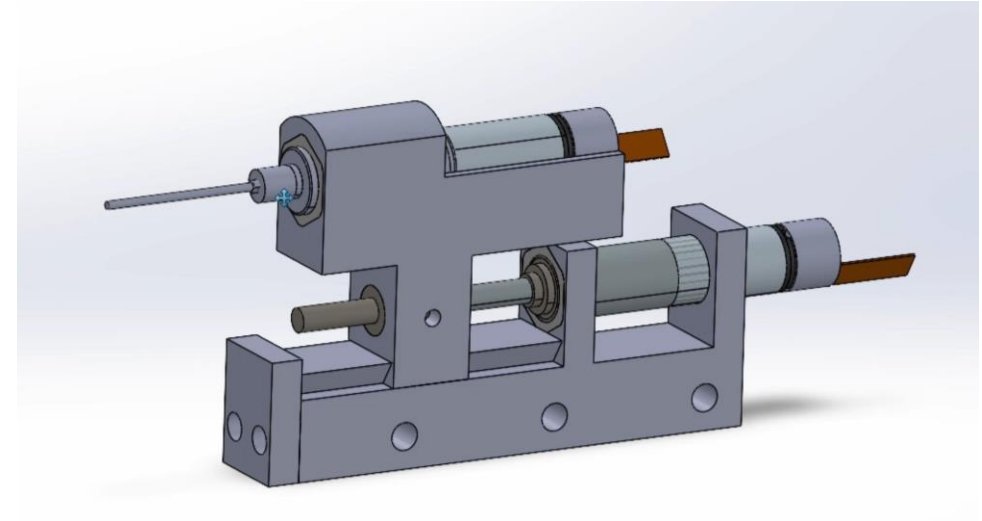
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- Tendon-driven guidewire that can bend a flexible region
- COAST prototype
- Compact advancement mechanism for a modified COAST
- Kinematic Modeling and Jacobian-Based Control



- Pros & Takeaways

- Precise advancement mechanism
- Systematic workflow
- Elaborate demonstration
- Detailed functional specification



- Cons

- Aim to develop an automation system for the guidewire navigation.
- Open-loop control and a visual-feedback system relying on trained surgeons.

- [1] Lis, P., Sarma, A., Trimpe, G., Brumfiel, T. A., Qi, R., & Desai, J. P. (2022, May). Design and Modeling of a Compact Advancement Mechanism for a Modified COAST Guidewire Robot. In 2022 International Conference on Robotics and Automation (ICRA) (pp. 1176-1182). IEEE.
- [2] Chitalia, Y., Wang, X., & Desai, J. P. (2018, May). Design, modeling and control of a 2-dof robotic guidewire. In 2018 IEEE International Conference on Robotics and Automation (ICRA) (pp. 32-37). IEEE.
- [3] Jeong, S., Chitalia, Y., & Desai, J. P. (2020). Design, modeling, and control of a coaxially aligned steerable (COAST) guidewire robot. *IEEE Robotics and Automation Letters*, 5(3), 4947-4954.
- [4] Sarma, A., Brumfiel, T. A., Chitalia, Y., & Desai, J. P. (2022). Kinematic modeling and Jacobian-based control of the COAST guidewire robot. *IEEE Transactions on Medical Robotics and Bionics*, 4(4), 967-975.
- [5] Pelton, A. R., Duerig, T. W., & Stöckel, D. (2004). A guide to shape memory and superelasticity in Nitinol medical devices. *Minimally Invasive Therapy & Allied Technologies*, 13(4), 218-221.

Thank you!

Q & A