Robotic Delivery of Engineered Tissue for Treating Aortic Disease

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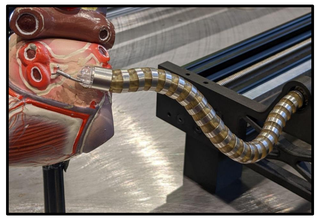
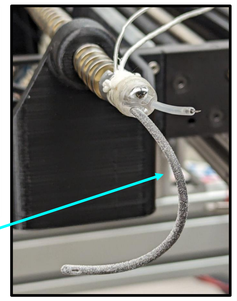
Motivation

The Medical Snake aims to perform minimally invasive in-vivo delivery of engineered tissue to treat aortic disease. We present system development on this robot platform that encompasses:

1) An off-the-shelf syringe pump to store and dispense this engineered tissue.
2) A custom 3D printed PLA device to actuate a tube out of the head of the robot.
3) An electromagnetic tracking system to display information on the snake's traveled path.





Dexterous Needle for deployment of this engineered tissue.

ECM Actuation Method

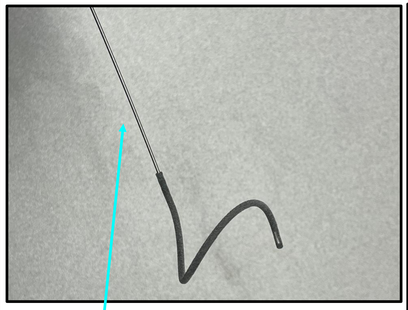
- We select **Bovine Type I Collagen** as the engineered tissue/extracellular matrix (ECM).
- It is widely available, cheap, and similar in viscosity to water.
- The off-the-shelf device used to deliver the ECM is the **NE-1002X One Channel**

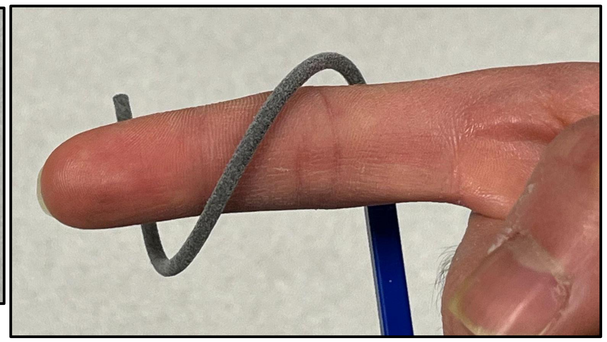
- Allows configuration of flow rate and dispensed volume, up to nanoliter accuracy.
- Supports a wide variety of syringe diameters.

Surgeon steps on foot switch, and the device starts infusing.

Properties of the Dexterous Helical Tube

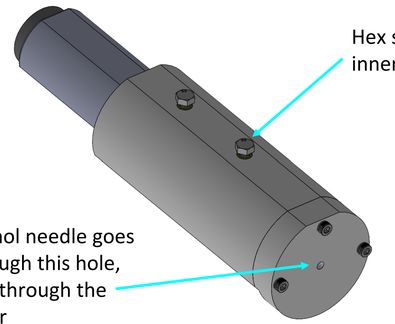
- This flexible tube was 3D printed with TPU88A. In the snake, it is straightened. But as it exits out of the snake's tip, the shape becomes a single helix, able to navigate around a vessel.
- We utilize this property to achieve "Follow-The-Leader (FTL)" motion, where the rest of the tube follows the tip's helical path, allowing ECM to be dispensed all around a vessel.





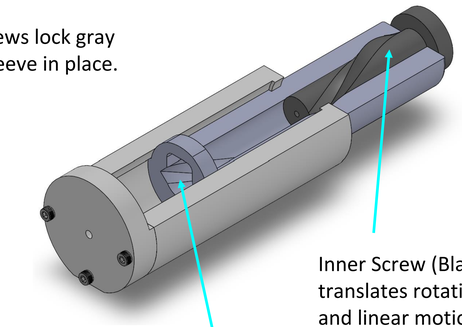
Attached to a superelastic nitinol tube. This tube will always be inside the snake's body, and ECM flows through this nitinol, then to the helical tube.

Helical Deployer: CAD Model and 3D-Printed Prototype



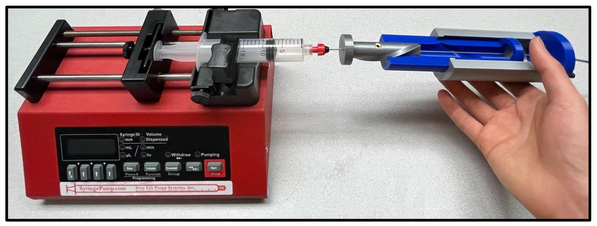
Hex screws lock gray inner sleeve in place.

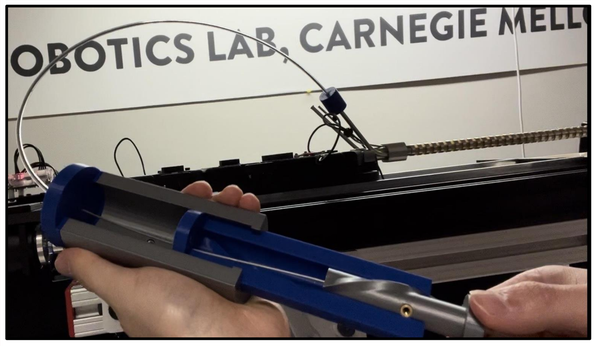
Nitinol needle goes through this hole, and through the inner screw/sleeve.



Inner Screw (Black) translates rotational and linear motion.

Inner Sleeve (Gray) translates linearly.



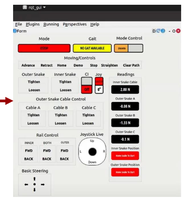


- This deployer actuates the helical needle to wrap around a vessel.
- First, the gray sleeve moves forward a distance approximately equal to the arc length of the helix.
- Then, turning the black screw about 40 degrees is required to maintain the helical "FTL" motion.
- If turning does not occur, the axis of which the helix revolves around will slowly tilt. Turning the helical needle while actuating it forwards counters this undesired motion.

Electromagnetic (EM) Tracking of the Snake's End-Effector

EM Tracking System

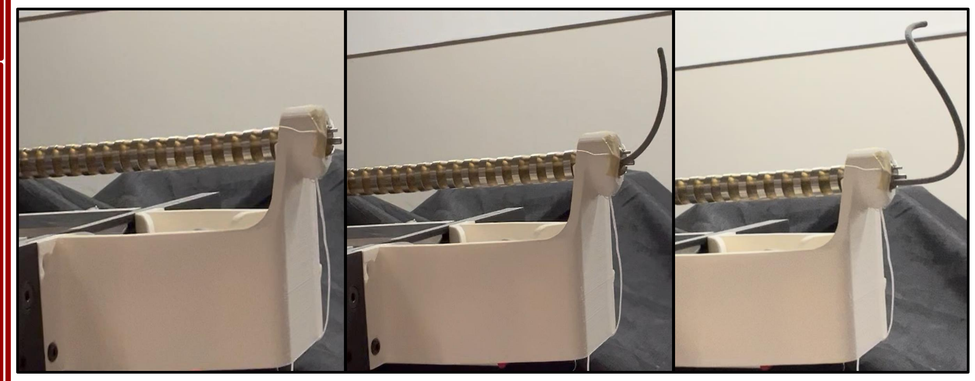
Sends Pose Data → ROS Node (C++) → Draws Path On



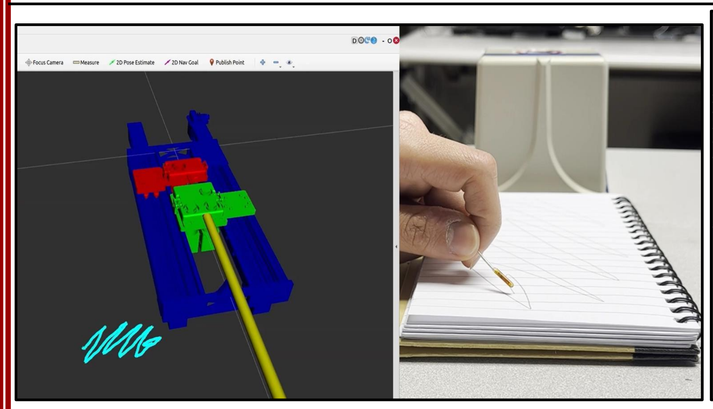
Medsnake Rviz GUI

- A pre-existing ROS Node acquires 3D pose (position and orientation) data between the EM transmitter and an EM-sensitive sensor, and publishes this data to a topic.
- This sensitive EM sensor is attached to the tip of the snake.
- A new ROS Node was written which subscribes to this pose topic. It records where the tip of the snake is in 3D space (The x, y, and z coordinates) relative to the transmitter, and uses these stored coordinates to draw a curve representing the path.

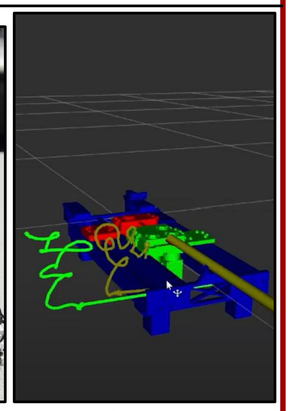
Demonstration: FTL Motion and RViz EM Visualization



Helical Needle "FTL" Motion, in 3 stages



EM Tracker Drawing a Predetermined Path



Tracking 2 Sensors

Future Work

- Testing this entire system on live porcine models.
- Converting the helical deployer into an electromechanical device, using a microcontroller, and a stepper motor, which is capable of both linear and rotational translation.

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