Robot for Remote Catheter Guidance through Blood Vessel Models

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Abstract

Aneurysm and blood clot removals, facilitated by blood vessel catheters, are critical to improving stroke treatment. The team was tasked to design and manufacture a remote-controlled robotic system that can translate and rotate a catheter through a benchtop blood vessel model. The system measures distance, force, and torque during testing and handles catheters of size 2-15 French. Robot size is 1.2 cubic feet, and measurements have a sampling rate between 5-30 Hz. The system measures forces between 0.1-10 N and includes an emergency stop feature if forces exceed 10 N. The team designed the robot in SolidWorks and primarily used additive manufacturing in its construction. The translation, rotation, and sensors were coded using Arduino. This project allows Bioengineering Devices Laboratory researchers to safely insert a catheter into a blood vessel model in the presence of x-rays. The system also demonstrates future capacity for surgeons to remotely operate on patients.

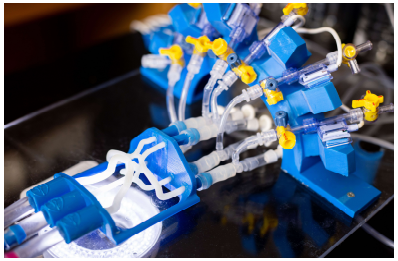

Figure 1. Benchtop blood vessel model

Requirements

- Catheter translation (2 ft) and rotation (360°)
- Remote control from at least 10 ft
- Instant data sampling at 5-30 Hz
- Emergency stop feature upon reaching 10 N
- Level system and prevent catheter kinking
- Variable catheter sizes (2-15 F or 0.67-5 mm)
- Calibration of force and displacement
- Measure push resistance force (0.1-10 N)
- Accuracy of force measurements (±0.05 N)
- Displacement resolution of 0.1 mm
- Equipment easy to replace
- Water resistant
- Ease of transport and assembly (under 1 ft^3)
- Temperature below 60°C

Methods

The final design contains parts designed in SolidWorks created from 3D-printed materials including PLA, ABS, Vero, and Agilus. Two stepper motors and load cells are used for translation, rotation, and subsequent data collection. Arduino code provides control of the robot and records measurements. To calibrate the load cells, weights of known values were applied to each load cell situated as a cantilever beam.

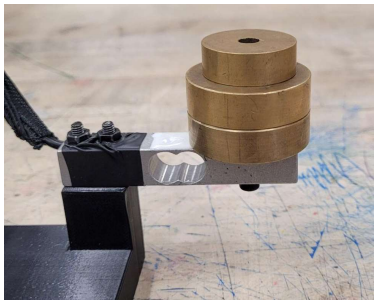

Figure 2. Load cell calibration

Results

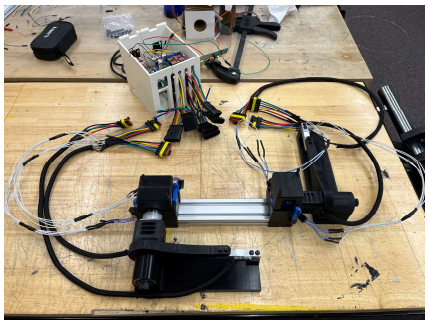

Figure 3. First full hardware assembly

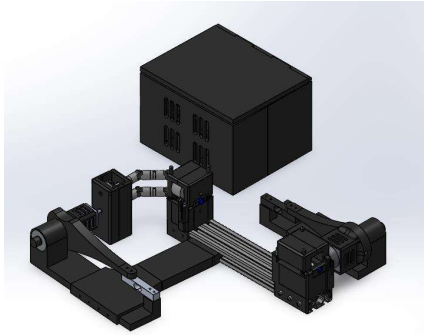

Figure 4. Final CAD model

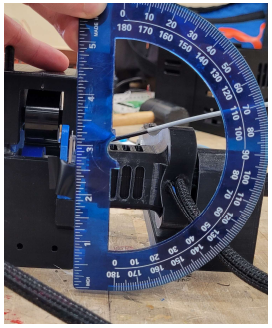

Figure 5. Catheter deflection

Conclusion

The final device meets or exceeds the engineering requirements with the following characteristics:

- Translation exceeds 2 ft
- Remote controlled from a maximum distance of 20 ft
- Measures push resistance forces
- Final volume of 1.2 ft^3
- 8 connectors between components for easy assembly and transport
- Emergency stop feature

The robot permits remote operation of catheters, preventing unnecessary exposure to x-rays when testing medical devices to treat stroke. This project also provides the opportunity to standardize testing to limit experimental variables when comparing different medical devices that are inserted via catheter. Future research has the potential to move this type of system from benchtop blood vessel models to clinical settings.

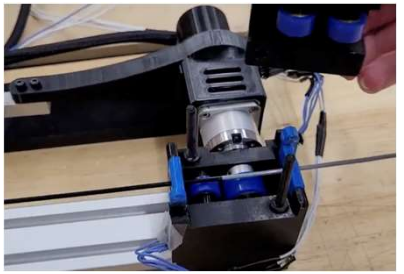

Figure 6. Catheter in translation system

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