Da Vinci Robot Haptic Feedback Gloves

Team
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Advisor
Professor Sheila Russo

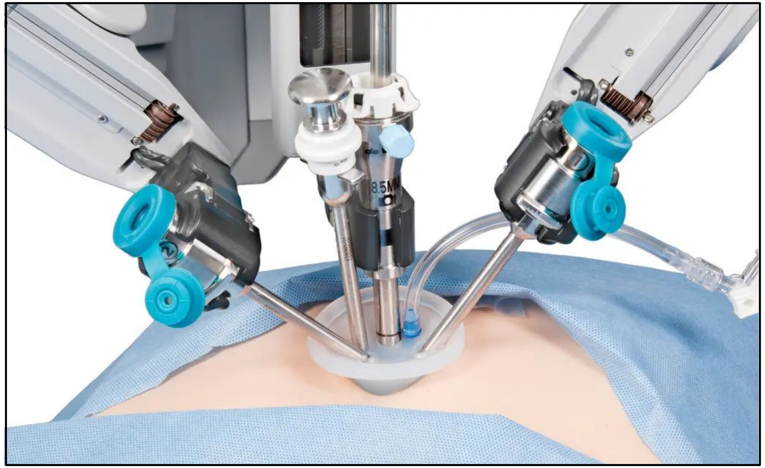
Problem Statement

Minimally Invasive Surgical (MIS) robots like the da Vinci Surgical System have reduced post-op care and recovery time for patients; however, the current design does not provide haptic feedback to surgeons.

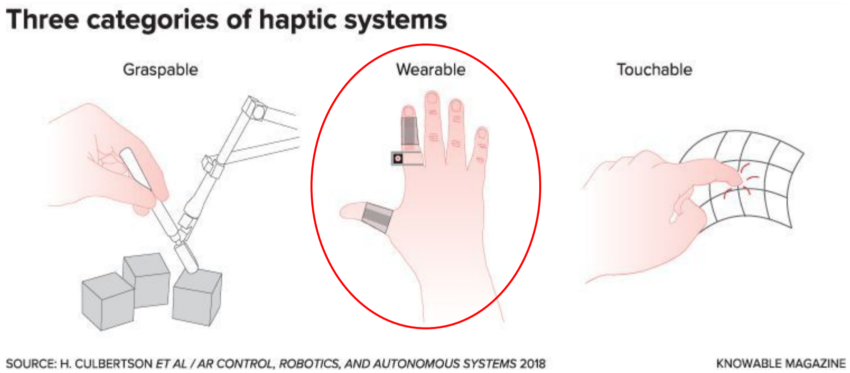
Project Description

Our goal is to design soft robotic gloves that provide haptic feedback when the pressure applied by the Cadiere forceps approaches the maximum pressure that human tissue can safely withstand.

Customer Requirements



- System must provide haptic feedback based on pressure applied by the Cadiere forceps.
- System must be sanitizable
- Design must be ergonomic and provide ample range of hand motion.



Metrics and Constraints

Metrics

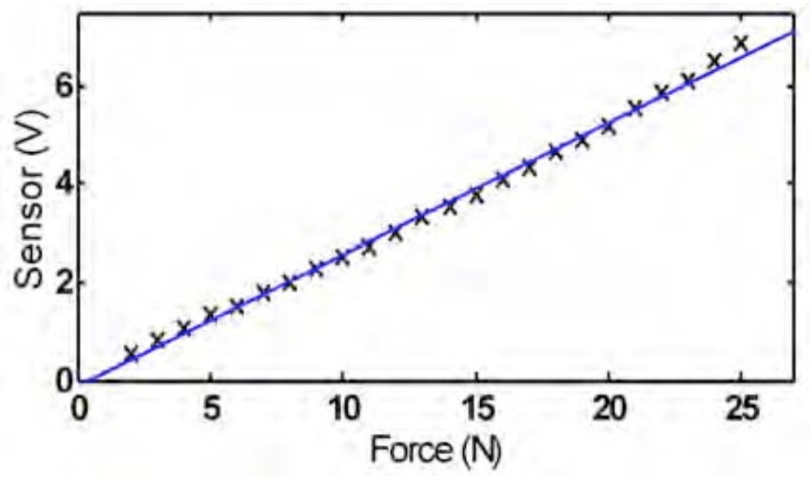
- **Sensor Dimensions**: The sensor must fit on tip of Cadiere forceps (7mm x 15mm).
- **Budget:** $400

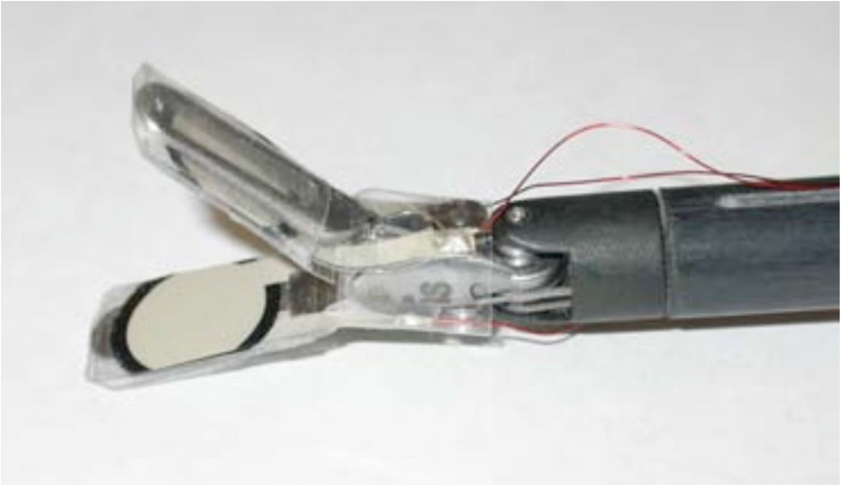
Constraints

- **Safety:** All wires and electronics must be properly sealed to avoid human contact.
- **Sterility:** The device must be sterilizable for medical use.
- **Durability:** The product must be reliable and robust for repeated use over an extended time period.

Benchmarking

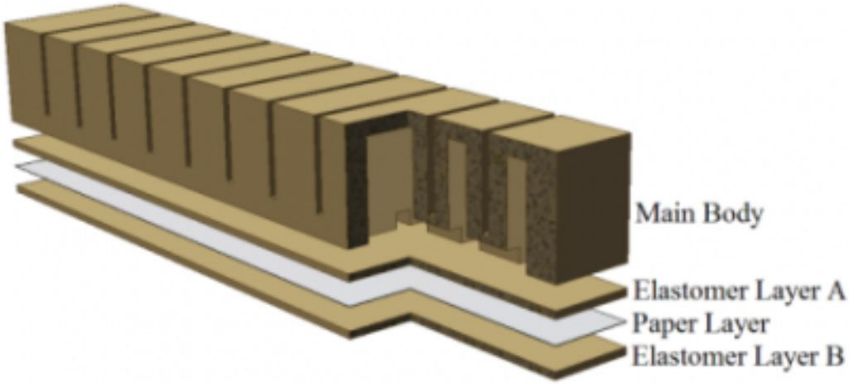
Benchmarking - Pressure Sensor

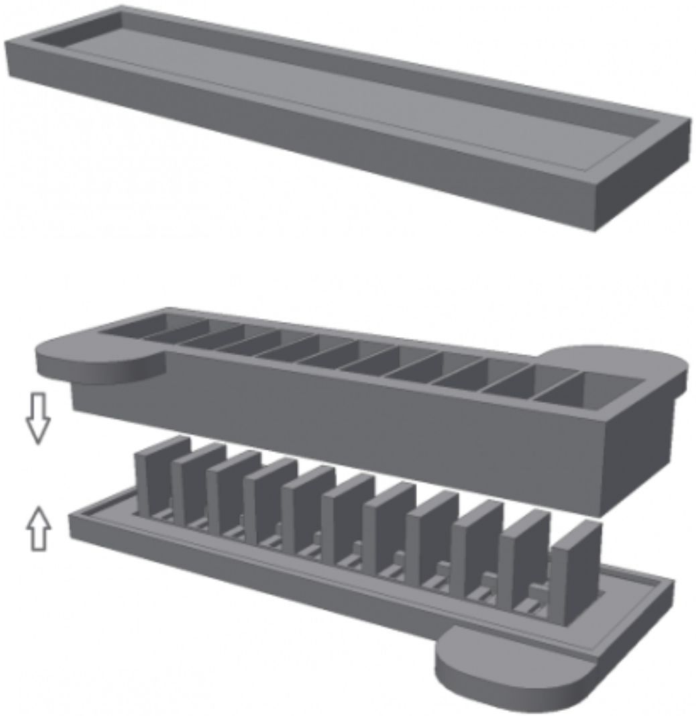




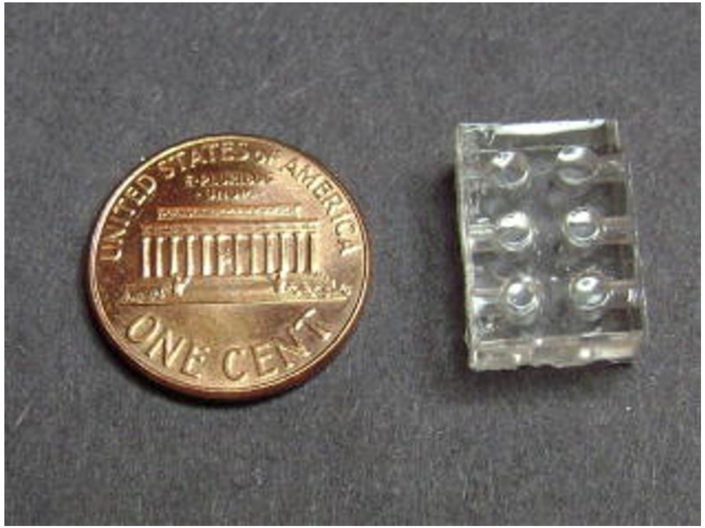
"A Tactile Feedback System for Robotic Surgery" by Martin O. Cultaj, et al.

Benchmarking - Actuator

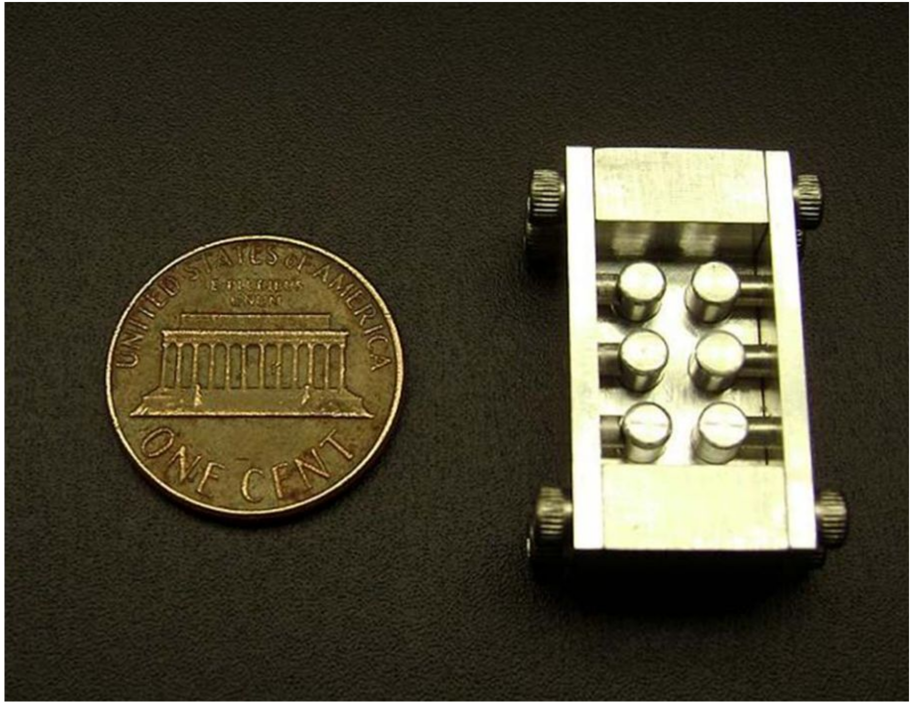




Benchmarking - Actuator



King, C. et. al. ASME Digital Collection



King, C. et. al. ASME Digital Collection

Most Significant Challenges

Sensor and Electronics

- Difficulty in finding a suitable sensor for the involved constraints.
- Calibration and integration of sensor caused some challenges due to noise in the signal.

Fluidic Controls

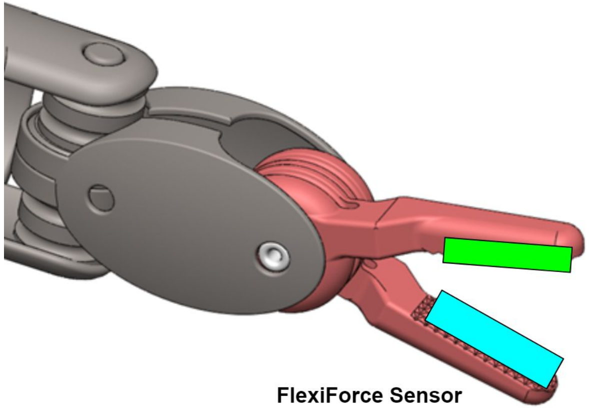
- Difficulty in determining how to build effective controls due to the low levels of pressures involved.

Actuator Design

- Finding a suitable design that would fit size constraints while providing enough pressure feedback.
- Unfamiliarity with soft robotics.

Design Evolution Over Time

Overall Design



Arduino Uno

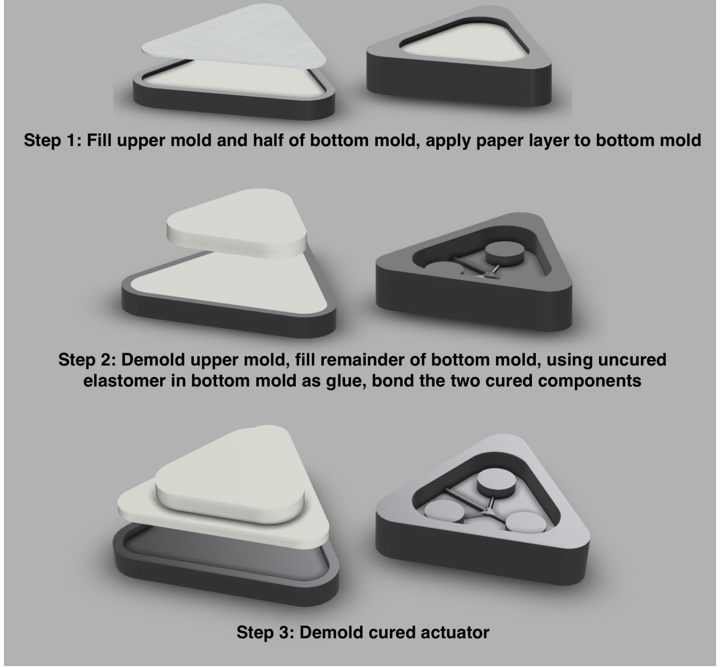
Electronics & Circuitry

Pneumatics

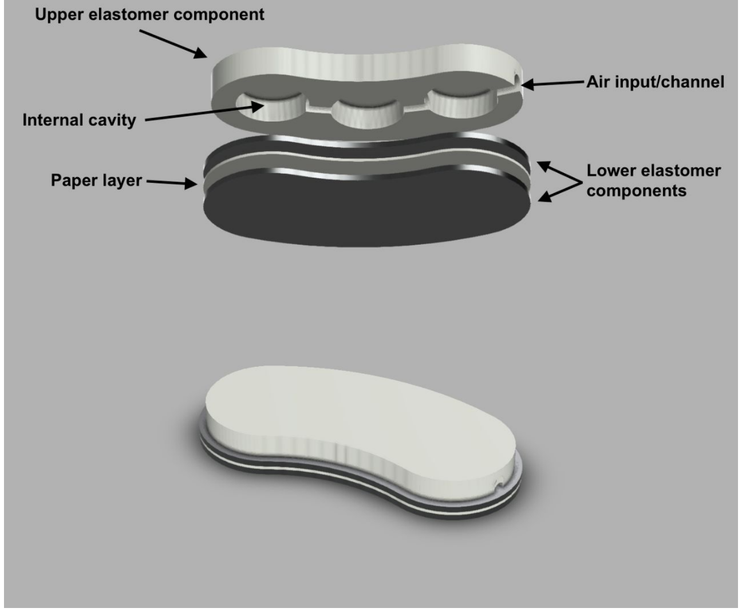
Fingerless gloves with embedded silicone actuators

Actuator Design Evolution

Preliminary Design (Molding Process)



Midterm Prototype Design

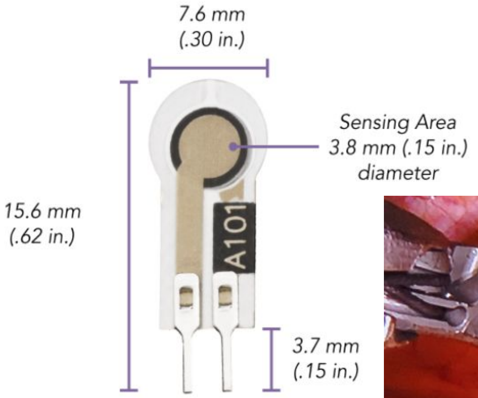


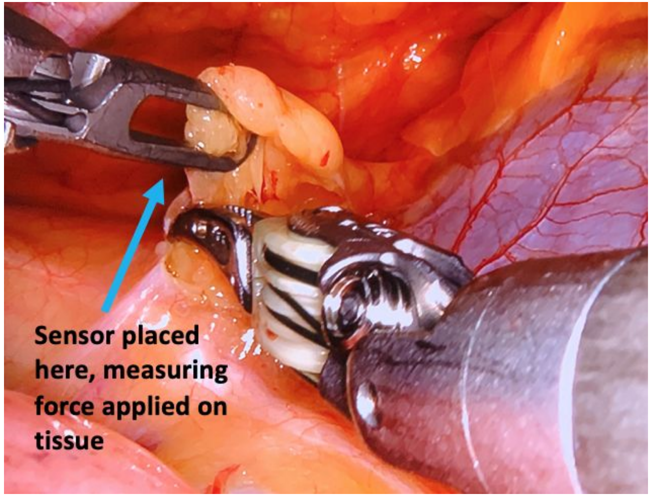
Sensor Selection

Tekscan FlexiForce A101 Sensor

Piezoresistive sensor is easy to use with the Arduino and is placed on the tips of the Cadiere forceps.

In the circuit, the sensor acts as a resistor. The resistance is high when the sensor is unloaded and is low when the sensor is loaded.



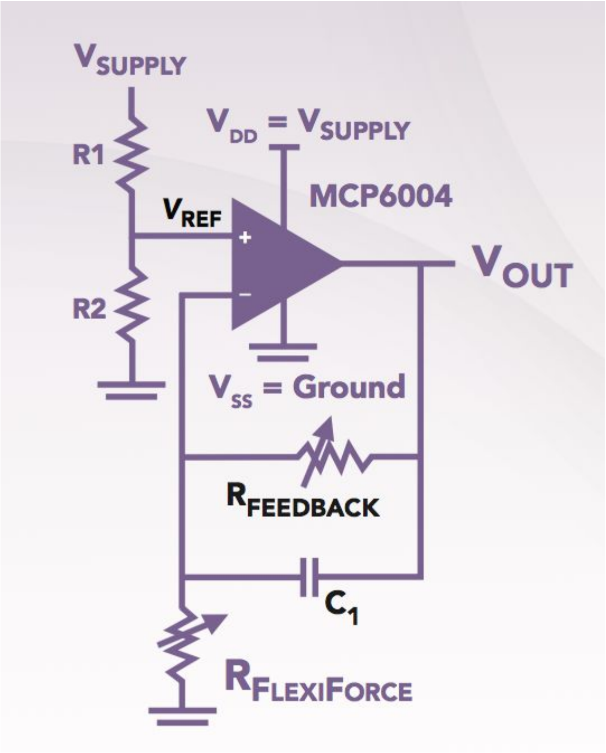


Sensor Circuitry

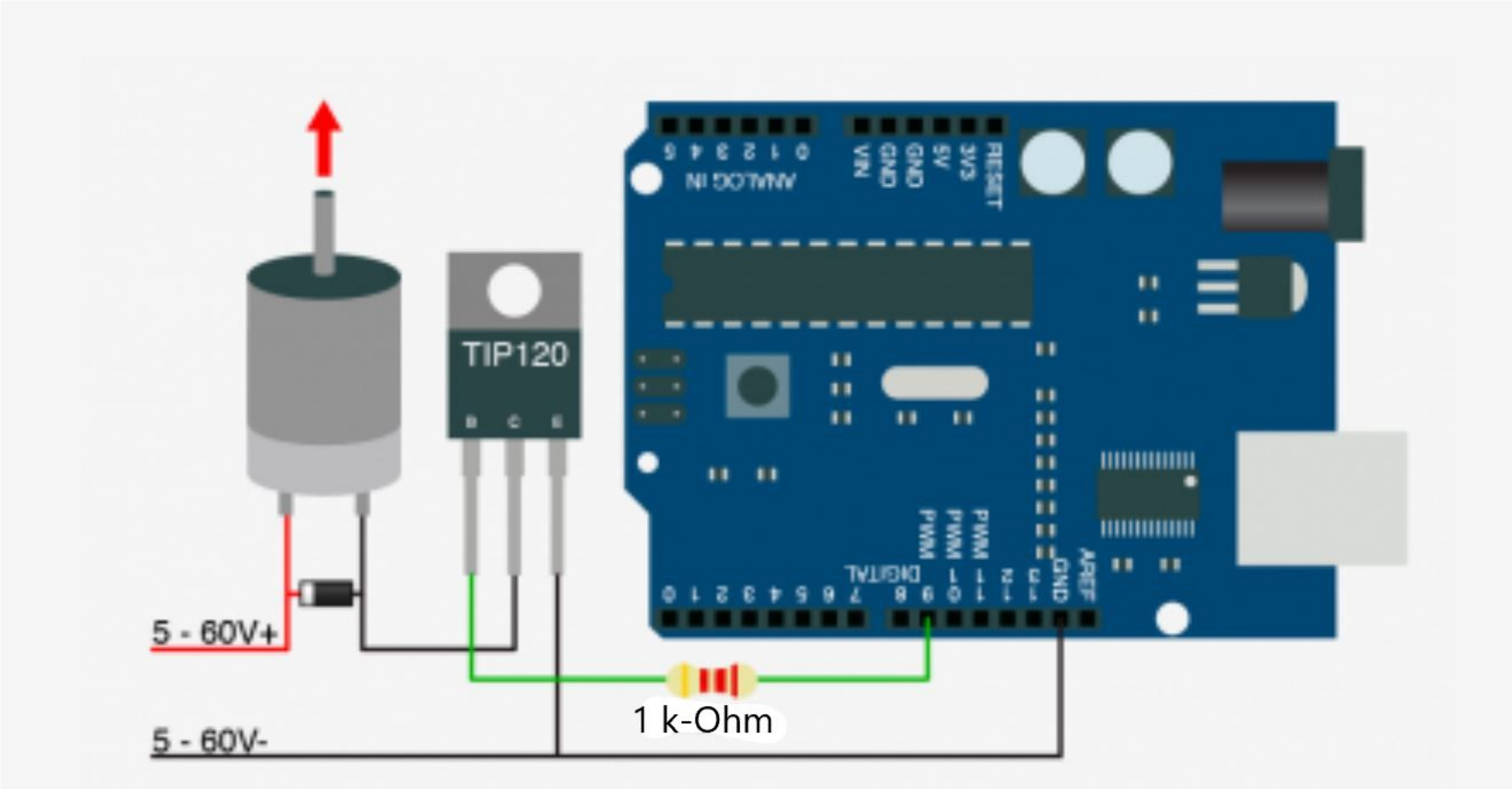
Tekscan Recommended Circuit

Integration of Flexiforce is done via non-inverting op-amp circuit.

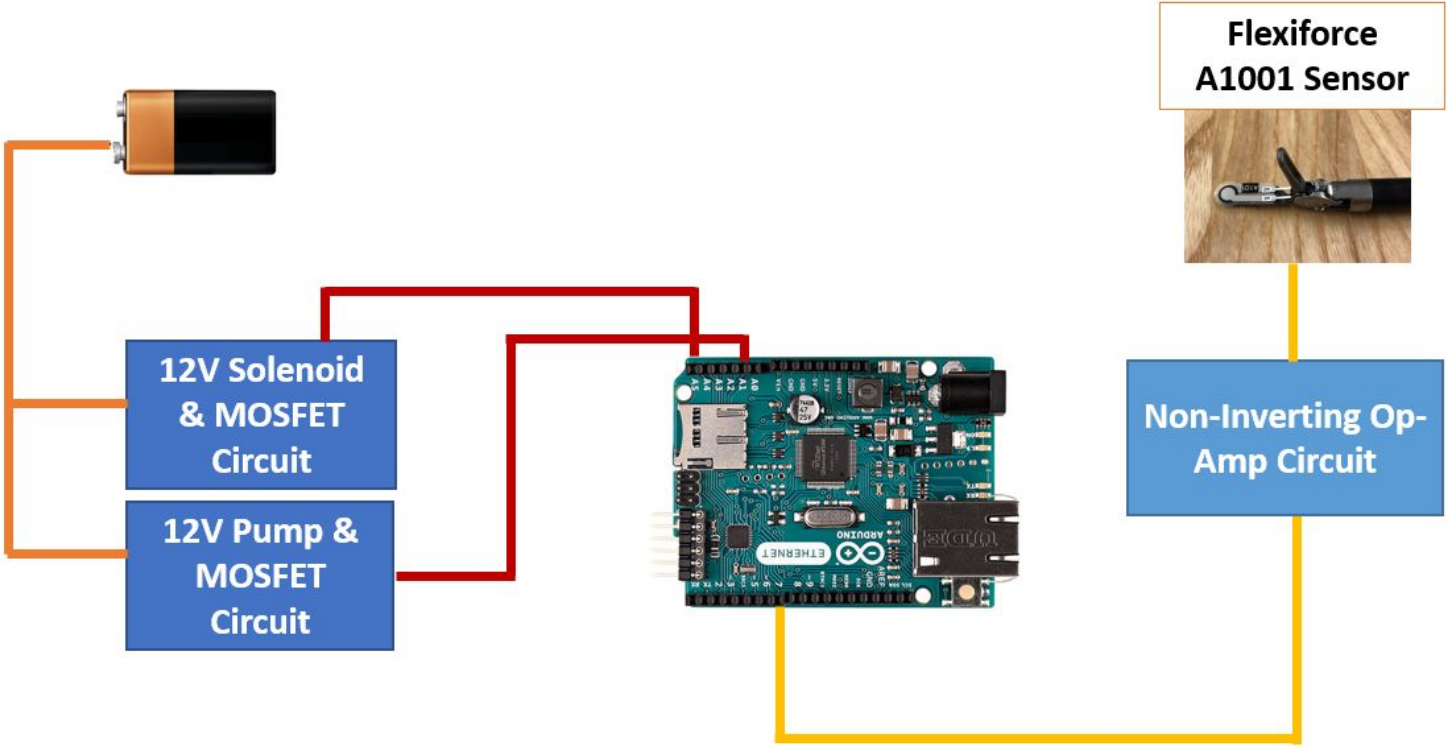
Feedback resistor and capacitor help to smooth out noise in sensor's response.



Actuator Pneumatics



Overall Controls Flow Chart

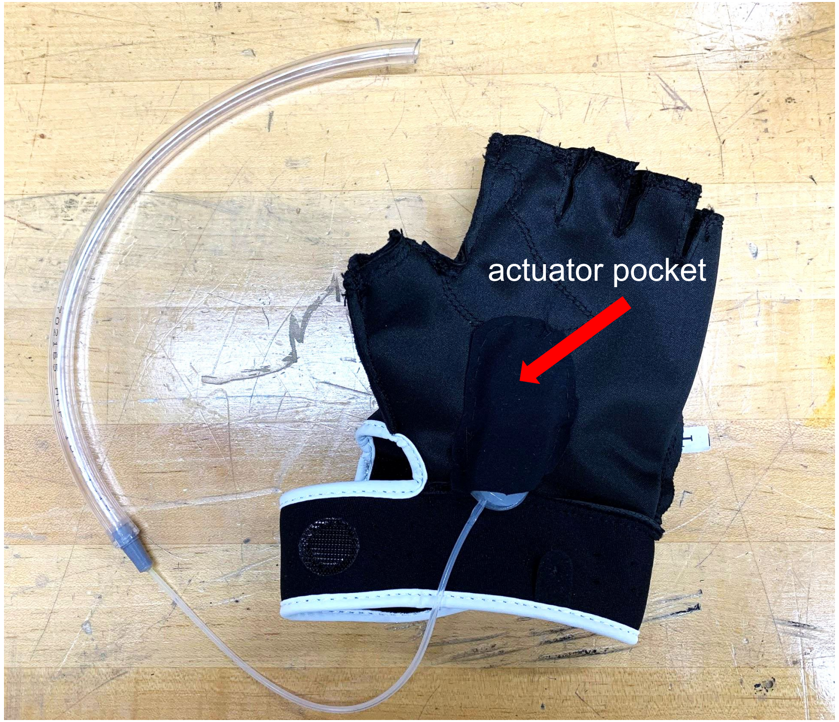


Glove Design

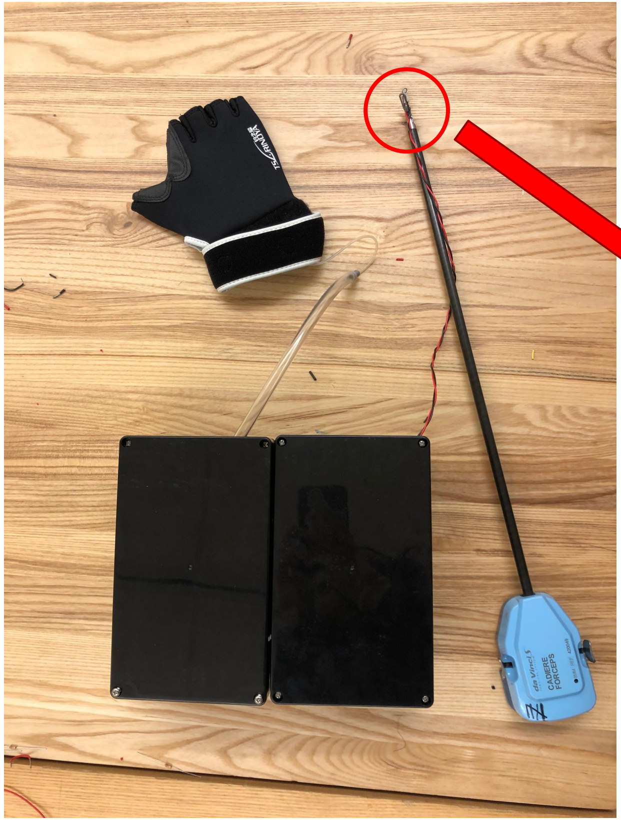
We used commercially available fingerless nylon gloves in our prototype.

The fingerless design allows the surgeon to more easily grip the controls.

A thin elastic fabric sewn into the palm of the glove interior serves as the actuator pocket.



Spring Midterm Prototype



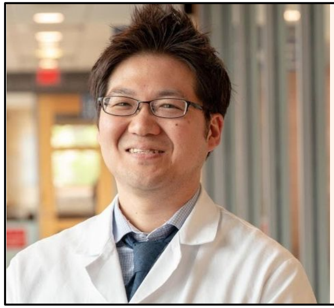
Status

Major Turning Point - Operating Room Visit

Thoracic Surgeon Dr. Suzuki invited the team to observe a surgery using the da Vinci Surgical System.

Dr. Suzuki pointed out that a glove could be constricting.

Alternative design: **Bracelet lined with actuator configuration.**

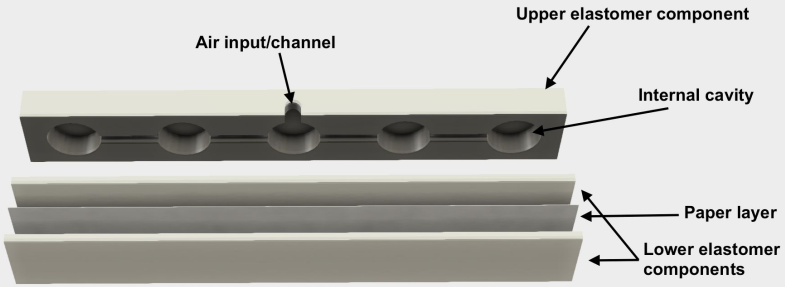


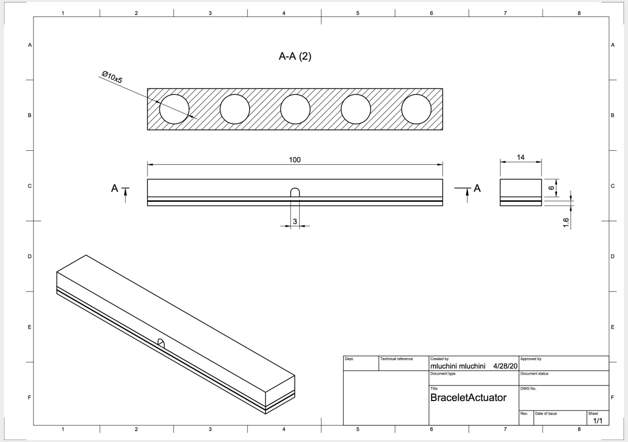
Kei Suzuki, MD

Thoracic Surgeon
Assistant Professor of Surgery, Boston University School of Medicine

GENDER: Male

Final Actuator Design - Bracelet Configuration





Acknowledgements

- A special thanks to Professor Russo for her continued guidance and support, we could not have done this without her.
- We would like to thank our senior design classmates and the students in the Russo Lab for their feedback throughout the spring semester.
- Dr. Suzuki’s design suggestions helped us make major improvements to our product. We are so thankful for the experience provided by him and the staff at the Boston Medical Center.
- Finally, we thank Professor Gutierrez and Professor Hauser for their leadership throughout the year.

Thank You! Any Questions?