Utilizing Hall Effect Sensors and Artificial Neural Networks to Classify Soft Magnetic Actuator Pose

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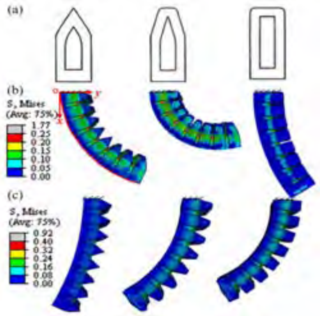
Background

- Soft robotics' high dexterity and safety make them ideal for biomedical applications
  - Ideal for gripping things, locomotion, and other biomedical devices, where the environment is highly dynamic and sensitive to physical interaction
- Soft pneumatic actuators are the dominant technology in soft robotics due to its low cost and mass, fast response time, and easy implementation



Background

- Ferrofluid - a liquid made of nanoscale magnetic particles suspended in a carrier fluid
- Dragonskin - basically stretchy/rubbery feeling silicone
- NPR Tool - is a machine learning technique that uses artificial neural networks (ANNs) to recognize patterns in different types of data. ANNs are computational systems that are modeled after the human brain and can learn to associate input patterns with output categories.
- Hall Effect Sensor - a sensor that measures the intensity of the magnetic field in volts
- Pose - position of the actuator in space

Research Gap

- Despite recent breakthroughs, soft pneumatic actuators and robots experience challenges related to integrated sensing and intelligent control.

- Mainly there is no effective way to measure where the actuator is in space (position) and what the shape is of the actuator at that time

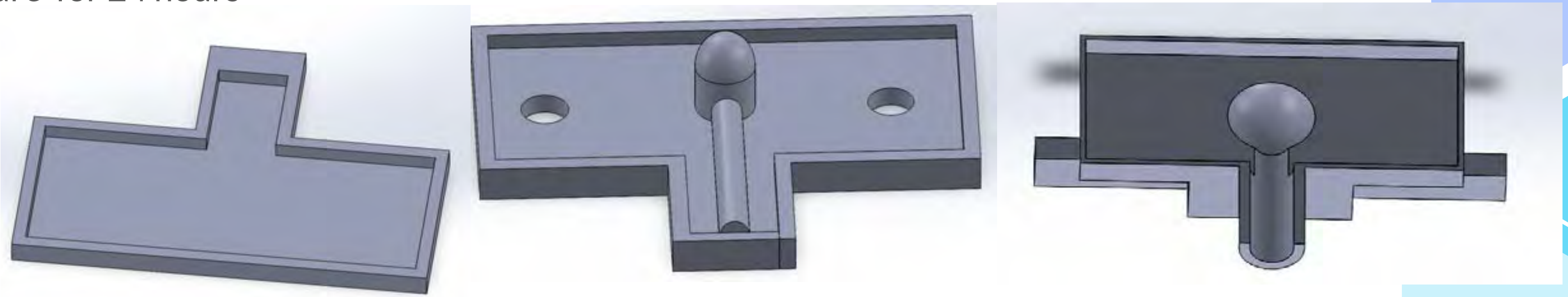
- These gaps are significant because without ways to actively and effectively control these actuators their use in biomedical and other important applications will be diminished

Techniques

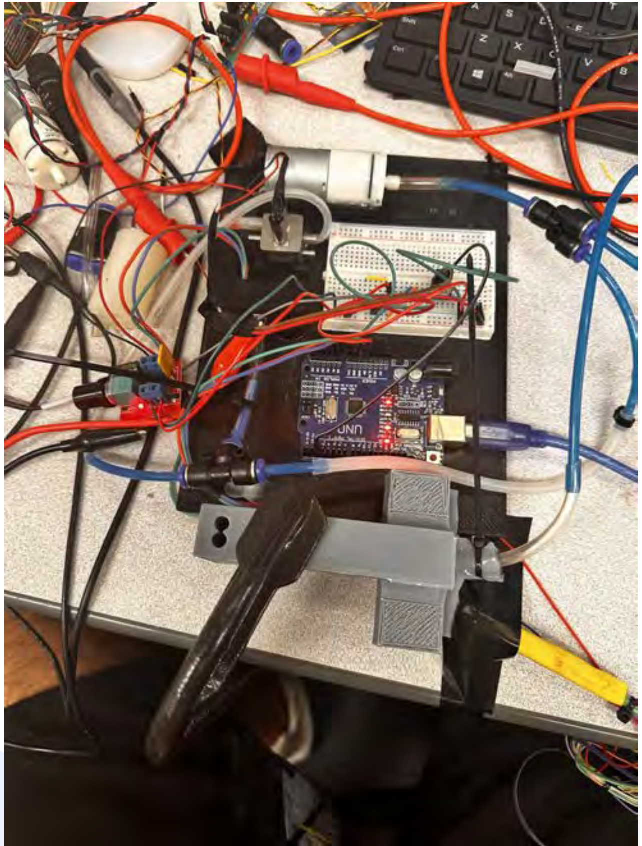
- Use a hall effect sensor which measures the intensity of the magnetic field along with a soft actuator made out of different ratios of magnetic material (ferrofluid) mixed with silicon
- Measure the displacement of the actuator based on the hall effect sensors reading of the magnetic field at specific pressures
- Train a neural network with the data from 3 different pressures for each different ratio of ferrofluid to silicon
- Test the neural network with training data to see which ratio of ferrofluid to silicon is best for determining the shape/pose of the soft actuator

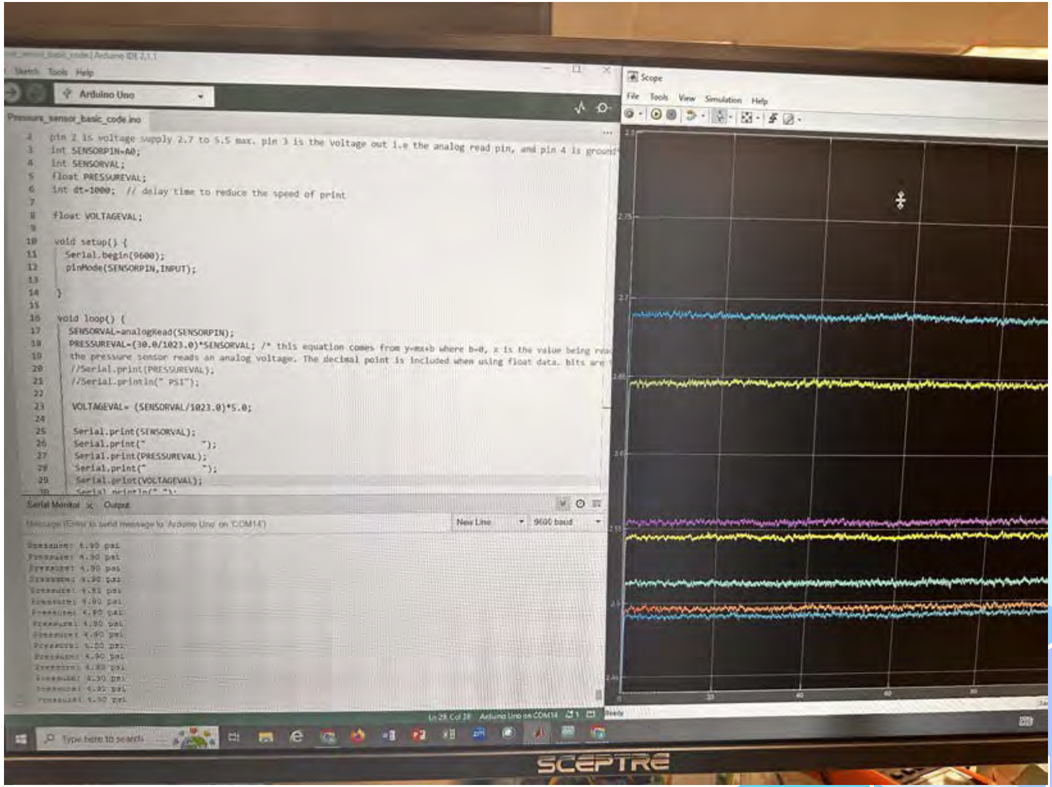
Actuator Manufacturing Process

1. Mix DragonSkin and Ferrofluid in a 85:15, 70:30, and 50:50 ratio
2. Pour into mold
3. Place tubing inside mold
4. Let cure for 24 hours

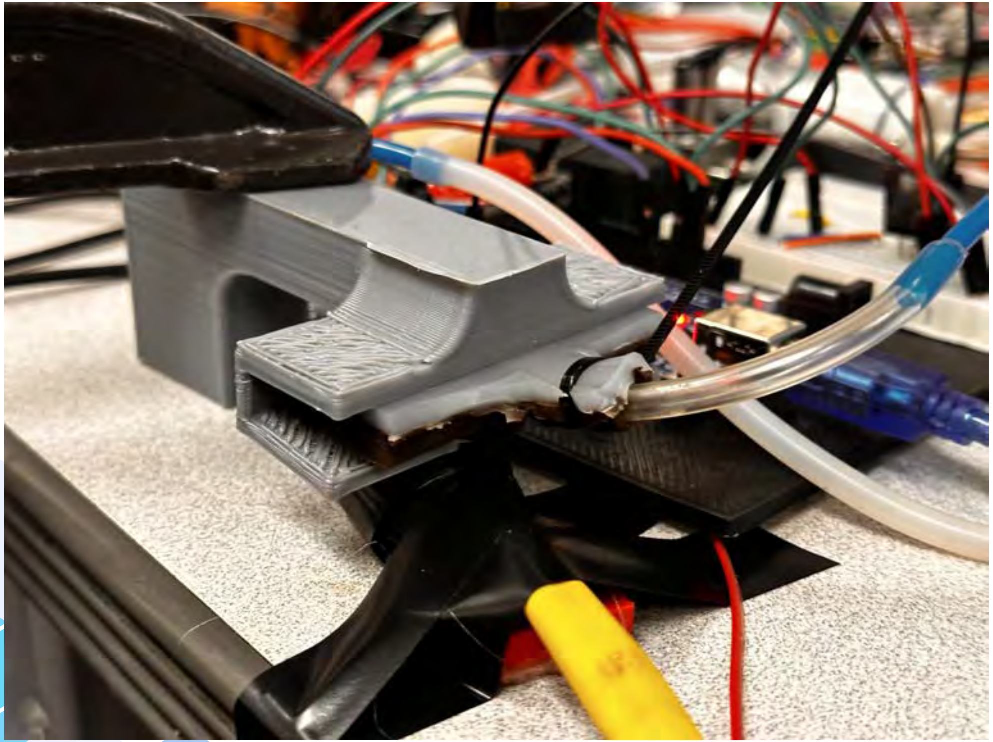


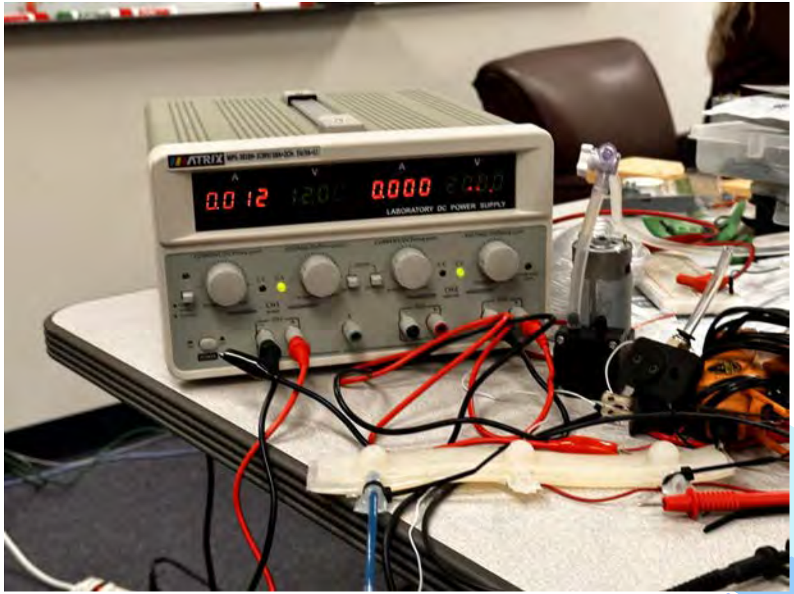
Set Up




Sketch Tools Help
Arduino Uno
Pressure_sensor_basic_code.ino
pin 2 is voltage supply 2.7 to 5.5 max. pin 3 is the voltage out i.e the analog read pin, and pin 4 is ground
int SENSORPIN=A0;
int SENSORVAL;
float PRESSUREVAL;
int dt=1000; // delay time to reduce the speed of print
float VOLTAGEVAL;
void setup() {
Serial.begin(9600);
pinMode(SENSORPIN,INPUT);
}
void loop() {
SENSORVAL=analogRead(SENSORPIN);
PRESSUREVAL=(30.0/1023.0)*SENSORVAL; /* this equation comes from y=mx+b where b=0, x is the value being
the pressure sensor reads an analog voltage. The decimal point is included when using float data. bits are
//Serial.print(PRESSUREVAL);
//Serial.println(" PSI");
VOLTAGEVAL= (SENSORVAL/1023.0)*5.0;
Serial.print(SENSORVAL);
Serial.print(" ");
Serial.print(PRESSUREVAL);
Serial.print(" ");
Serial.print(VOLTAGEVAL);
Serial Monitor
Output
New Line
9600 baud
Scope
File Tools View Simulation Help
SCEPTRE

Set Up





Results

Hall Effect Signal Data

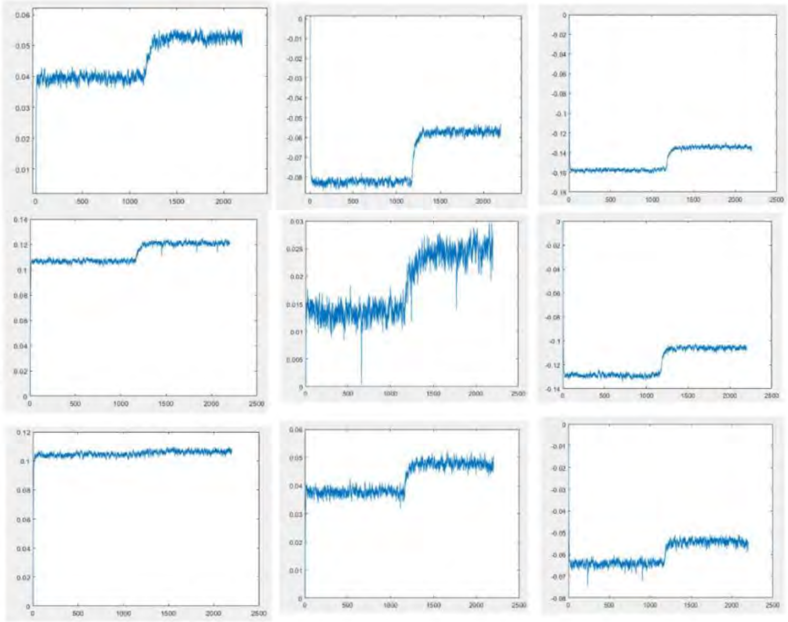


Figure (5). Signals from each of the 9 hall effect sensors during the 10-psi test

Confusion Matrix

Results

- Use Matlab NPR tool (Neural Net Pattern Recognition) to train on the pressures selected for each actuator
- Input experimental data for each pressure and output the classification accuracy of the neural network for each different combination of Ferrofluid:Dragonskin actuator
- Figure out whether or not the amount of ferrofluid in the actuator impacts the hall effect sensor's ability to get consistency in data
- Make recommendations on the amount of ferrofluid to use when making Soft pneumatic actuators and whether hall effect sensors work for control/sensing of actuators

References

Hsiao, Jen-Hsuan & Chang, Jen-Yuan & Cheng, Chao-Min. (2019). Soft medical robotics: clinical and biomedical applications, challenges, and future directions. Advanced Robotics. 33. 1-13. 10.1080/01691864.2019.1679251.

H. Xu, P. Agarwal and B. Stephens-Fripp, "Constant Fluidic Mass Control for Soft Actuators Using Artificial Neural Network Algorithm," 2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Prague, Czech Republic, 2021, pp. 1732-1739, doi: 10.1109/IROS51168.2021.9636630.