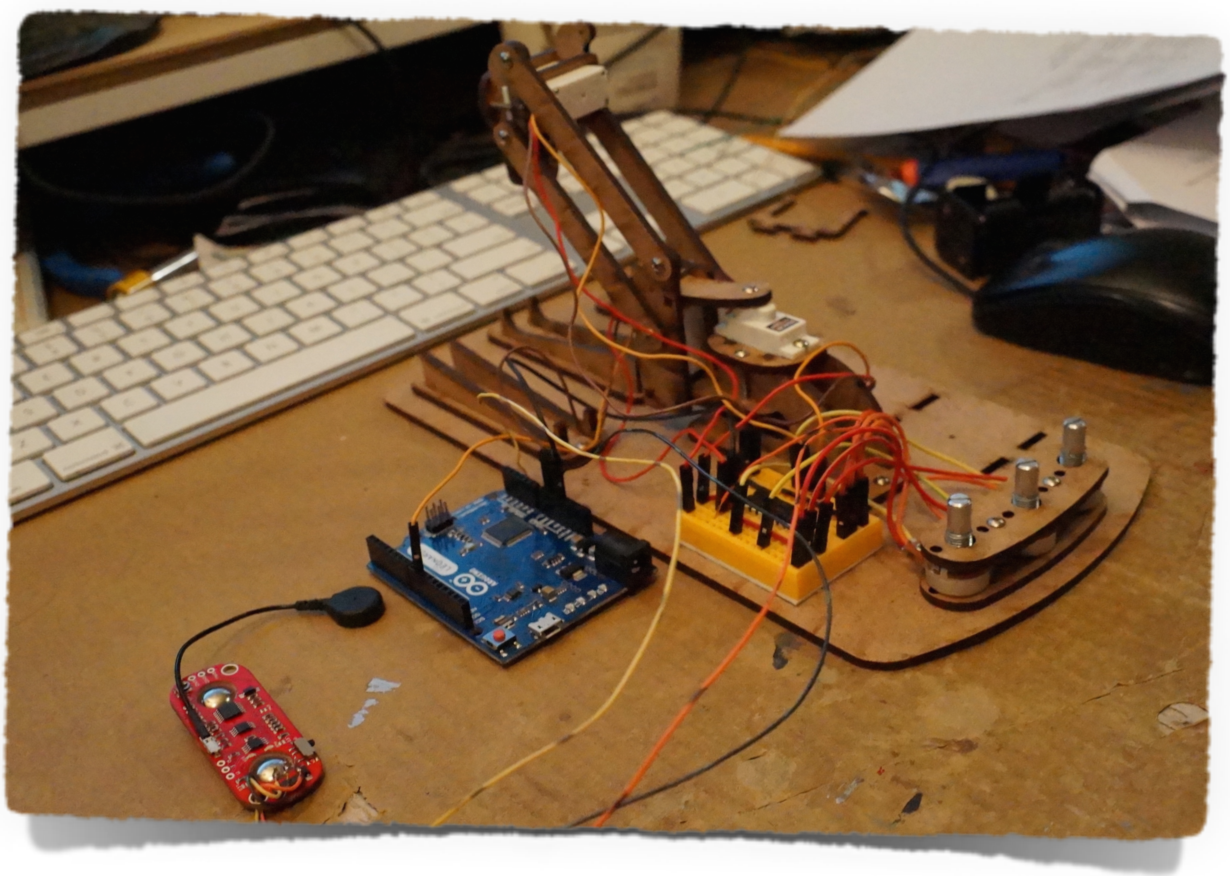
Muscle Sense

STEM Fair



Andrew Pun
Feb 10, 2017

Abstract

Electromyography (EMG) measures the electrical potential in a muscle. In order for a muscle to contract, the brain sends out signals, giving commands to the muscle to move. Electromyographic sensors detect these signals. The sensor can convert these signals into a voltage, and the computer digitizes the voltage into numbers, which can be used to control external hardware.

In this experiment, an electromyographic sensor called the Myoware sensor will be attached to an Arduino microcontroller. This microcontroller can take the inputs of the sensor, and power a servo motor. A serial monitor on the computer will show the voltage of the sensor, and the experimenter will use this data to observe. The experimenter needs to determine which position on an arm muscle will give the highest results. The sensor will be placed a certain distance from the inner elbow, and each time, results will be analyzed.

After the observations were recorded, the data was analyzed. The experimenter found that every time the participant moved his arm, the electromyographic value would shortly spike up, due to a surge in electrical signals when the muscle was commanded to move.

In the real world, electromyography plays a big role in medicine. Prosthetics are controlled by EMG sensors that detect flexing of the amputee's remaining muscle, and control motors in the prosthetic limb. EMGs also detect neuromuscular diseases.

Defining Terms

Electromyography (EMG) - The recording of electrical activity from a muscle.
MyoWare Sensor - A brand-name electronic sensor that measures electromyography.
Motor Neurons - Nerve cells located in the spine that have fibres extending that control other organs.

Electrode - A conductor in a circuit used to measure non-metallic parts of a circuit (in this experiment it will be the human skin).
Arduino - A microcontroller that uses an open-source programming language.
Servo Motor - A motor with a third lead that measures an electronic pulse, and precisely positions itself based on the pulse.

Purpose

Electromyography is used in prosthetics to help an amputee consciously control an artificial limb. The purpose of this experiment is to find the most desirable position on a person's bicep muscle to place an electrode sensor to achieve the highest electromyographic value, which can then be used to control a robotic arm attached to the sensor. After finding the highest value, the robotic arm can be calibrated to further accommodate the range of the sensor, to create an arm that moves smoothly.

Problem

What is the desirable position on a person's upper arm muscle to place the sensor, to ensure that the maximum myoelectrical value is achieved?

Hypothesis

If the sensor is placed directly on the belly of the biceps, then the sensor will be very responsive as that part of the muscle is very dense in muscle tissue. Placing the sensor 10 cm away from the inner elbow will be on the direct centre of the biceps and will most likely have an increased amount of electrical activity. Multiple motor neuron units may be present in the dense muscle fibres.

Experimental Design

What was the desirable position to place the MyoWare sensor on the human arm to ensure the most responsive results?

The experimenter created a robotic arm that changed position via the value of the MyoWare sensor. This was powered by an Arduino microcontroller.

An Arduino code was written for the sensor.
Positions on the participant's upper arm were marked for the sensor to be placed on. The positions were marked as 0 cm, 2.5 cm, 5 cm, 7.5 cm and 10 cm.

A servo motor was used by the robotic arm, as it precisely attained certain positions based on electrical current, which was sent by the sensor.
The Arduino code used the sensor value to command the servo motor to move in a certain position. Another Arduino code displayed numbers on the monitor that showed the sensor values.

The experiment was conducted and data was drawn. The data was put onto a table and a graph, and analyzed.

Placing the sensor 2.5 cm away from the inner elbow proved the highest values. It seemed that there was a pattern with each sensor value every time the participant moved his arm. It would go up in value every time the muscle moved, and came back down when the arm stayed idle, even in that position.

Because the participant moved his arm without applying much force, there was no need for a lot of motor neuron units in the bicep to use, and thus, the signal was weaker in the belly of the muscle than the outside.

These results did not support the experimenter's hypothesis. The best area to put the sensor was not directly in the centre of the muscle.

Variables

Independent Variables

- **Position of sensor** - This will be adjusted by how far away the sensor will be from the inner elbow.

Dependant Variables

- **Electromyographic values of sensor** - This will be manipulated by flexing the arm, and the intensity will rely on the position of the sensor.

Constant Variables

- **Intensity of muscle contraction** - The muscle will be lifted up to the same height and force each time.
- **Electrical interference** - It is virtually impossible to eliminate these interferences, but it is possible to keep it at a minimum by keeping the experimental environment the same and away from most electronic devices.
- **Participant's arm** - The participant's arm should stay constant. Different people have a different amount of overlying tissue. Only one person should be used for this experiment.
- **Quality of contact between electrode and arm** - The electrodes should be brand new and the gel under the electrode should stay moist.
- **Elevation of flexing** - Participant will raise arm to the same height each time.

Materials

- MyoWare sensor
- Electrodes x 3
- Arduino microcontroller
- Servo motor
- Robotic arm powered by servo motor
- 3-pin header
- 3-pin header connector
- Soldering iron
- Lead tin solder
- Breadboard
- 4 wires

- Micro USB cable
- Ruler

Apparatus

- Computer

Safety Precautions

Always run the Arduino microcontroller on a low voltage source, such as a computer or a battery pack. A high voltage battery pack may short and sometimes discharge a dangerous amount of electricity to the user's arm. Be very cautious when operating a soldering iron. Soldering irons function at extremely high temperatures, and lead fumes from solder are toxic. Use under adult supervision. Do not handle any electronic components without being free of static. Electronic components are usually electrostatic sensitive and a static discharge from the user's hand may damage it. Do not place the microcontroller on a metallic surface. This may short the component and cause damage.

Control Test

The purpose of the control test is to isolate potential errors as electronic disruption when measuring electrical activity of the muscle. This information will be useful during the analysis of the experimental setup. The sensor will be set at 0 cm away from the inner elbow (known as the *cubital fossa*) where the tendon is. The control test can serve as a baseline to compare other data values from the experimental setup.

Procedure

1. The control wire (usually yellow) of the servo motor was connected to pin 9 of the Arduino.
2. The ground wire (usually black or brown) of the servo motor was connected to one of the ground pins on the Arduino.

3. The positive wire (usually red) of the servo motor was connected to one of the terminal strips on the breadboard.
4. A 3-pin header was soldered onto the right side of the Myoware sensor (the side that was labelled positive, ground and signal) pointing up.
5. 3 wires were connected to a 3-pin header connector. The connector was connected to the sensor via the header.
6. Connect the ground wire of the 3-pin header connector to one of the ground pins on the Arduino.
7. The positive wire of the 3-pin header connector was connected to the terminal strip on the breadboard. It was added to the same column as the positive wire on the servo motor.
8. The signal wire of the 3-pin header connector was connected to the Analog In pin A0 of the Arduino.
9. A wire was used to connect the breadboard and the Arduino. One of its ends was connected parallel to the positive wire on the servo.
10. The following code was written and uploaded onto the Arduino. The serial monitor for the Arduino was turned on and observed for the next segment of the experiment. Note that the robotic arm is non-functional during this part of the experiment.

```
void setup() {
 Serial.begin(9600);
}

void loop() {
 int sensorValue = analogRead(A0);
 Serial.println(sensorValue);
  delay(100);
}
```

11. 3 electrodes were attached to each pin of the MyoWare Sensor.
12. The sensor was placed correctly on the participant's arm, 0 cm away from inner elbow. As the participant moved his arm up and down 5 times, results were recorded.

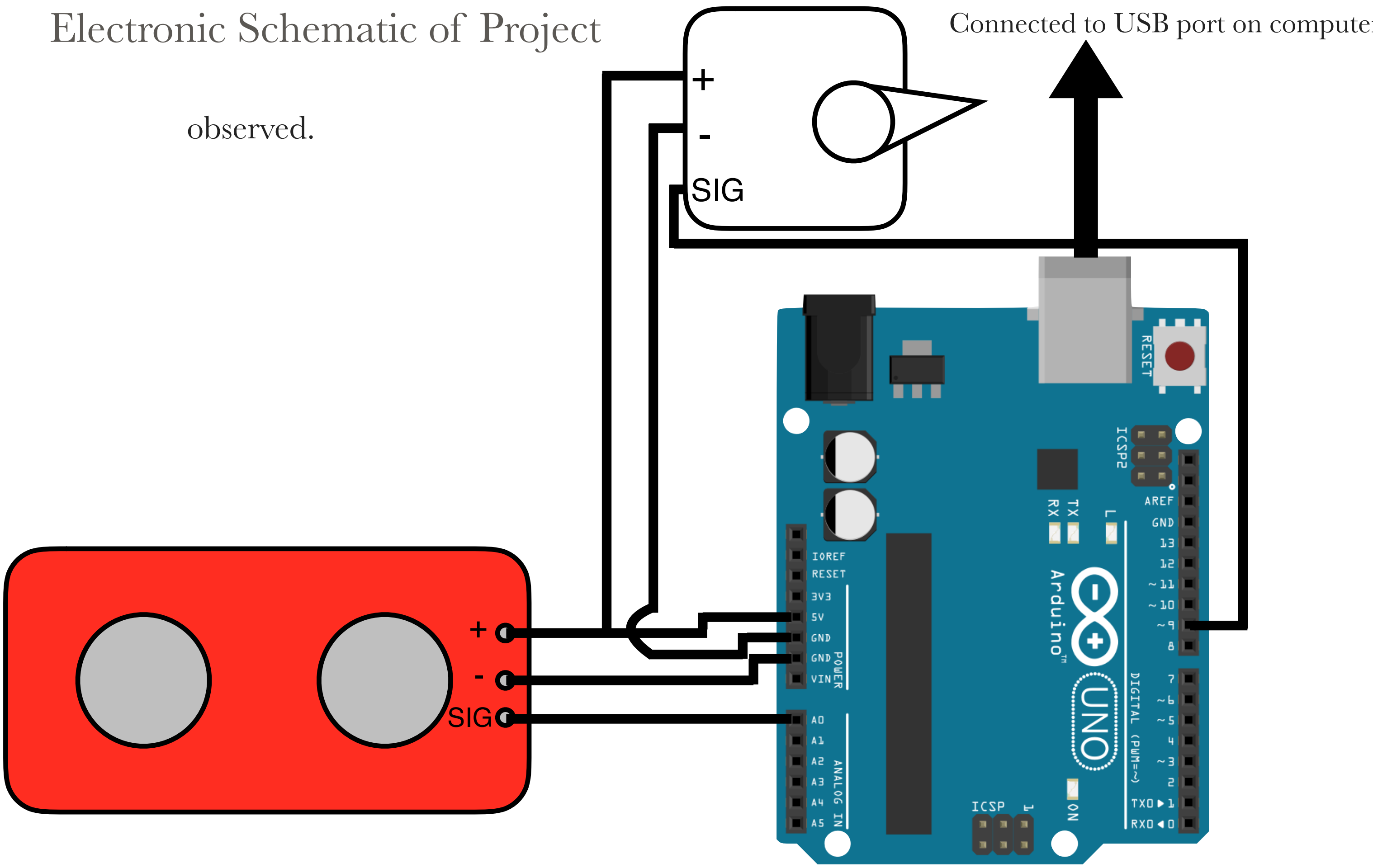
13. The sensor was moved 2.5 cm away from inner elbow. As the participant moved his arm up and down 5 times, results were recorded.
14. The sensor was moved 5 cm away from inner elbow. As the participant moved his arm up and down 5 times, results were recorded.
15. The sensor was moved 7.5 cm away from inner elbow. As the participant moved his arm up and down 5 times, results were recorded.
16. The sensor was moved 10 cm away from inner elbow. As the participant moved his arm up and down 5 times, results were recorded.
17. The following code was uploaded to the Arduino.

```
void setup() {int sensorPin = A0;
int sensorValue = 0;
int inputCorrect = 0;

#include <Servo.h>
Servo myservo;


  pinMode(sensorValue, INPUT);

  myservo.attach(9);

}

void loop() {

  sensorValue = analogRead(sensorPin);

  if (sensorValue > 500)
  {
  myservo.writeMicroseconds(2000);
  }
  else
  {
  myservo.writeMicroseconds(sensorValue+1500);
  }
```

}

18. The experiment was done again and movement of the robotic arm was observed.

Electronic Schematic of Project



Observation Description

During the observation, the robotic arm moved as accordingly during all the experiments. However, sometimes it did not move smoothly because of noise in the signals. On Trial #1, placing the sensor 2.5 cm away from the inner elbow gave the highest average, at 509.2. Placing the sensor 5 cm away from the inner elbow gave the lowest average, at 96.8. Other than 2.5, the rest of the locations were lower than the control test. On Trial #2, placing the sensor 2.5 cm away from the inner elbow gave the highest result, at 486. Placing the sensor 5 cm away from the inner elbow gave the lowest average, at 150.4. However, this time, placing the sensor 7.5 cm and 10 cm away from the inner elbow gave a higher average than the control test. As the participant's arm moved, the sensor value increased in numbers for a brief amount of time, then started to decrease when his arm remained idle in a fixed position. When the arm was moved down to rest on the table, another peak was observed.

Data Column

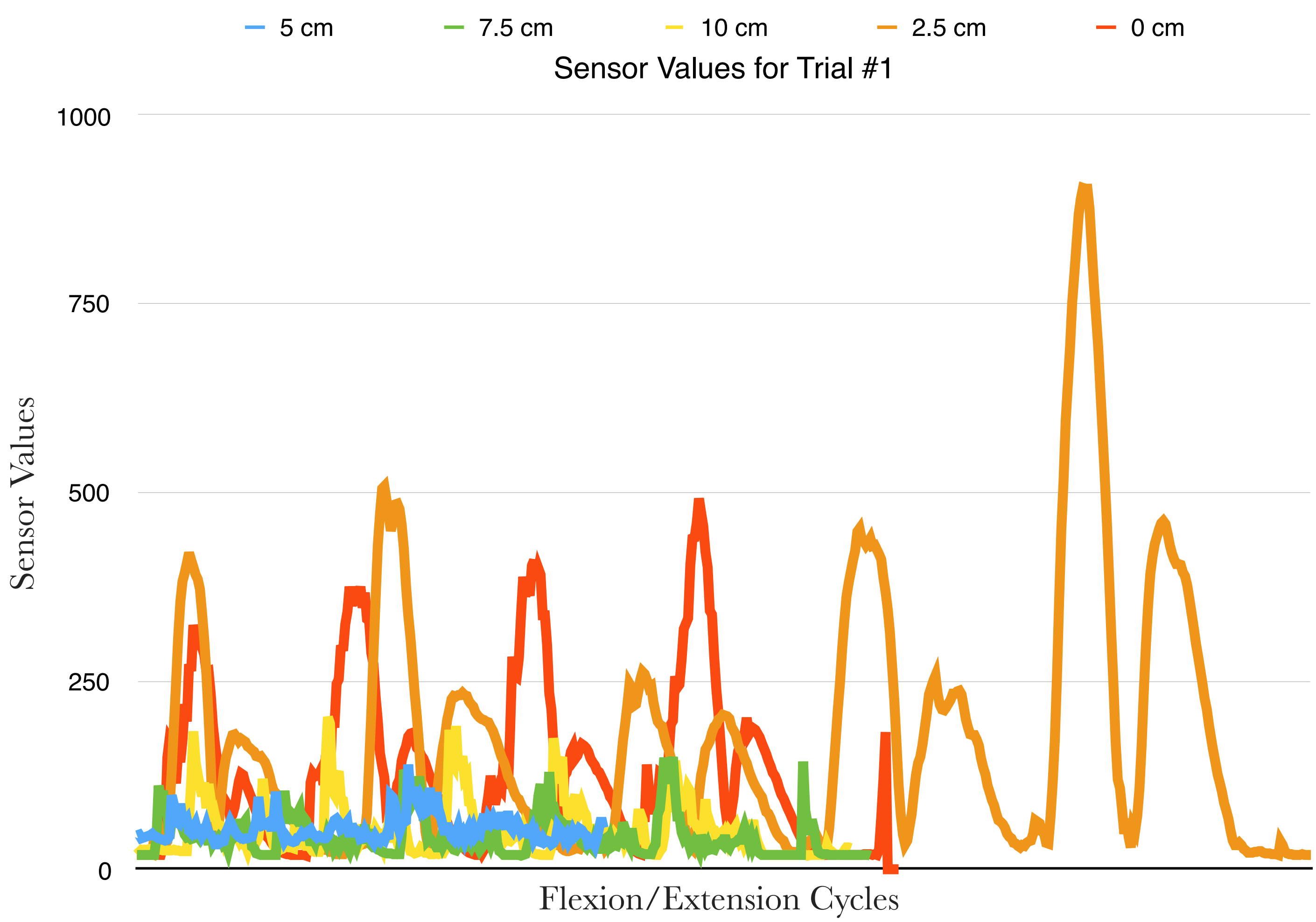
Trial #1

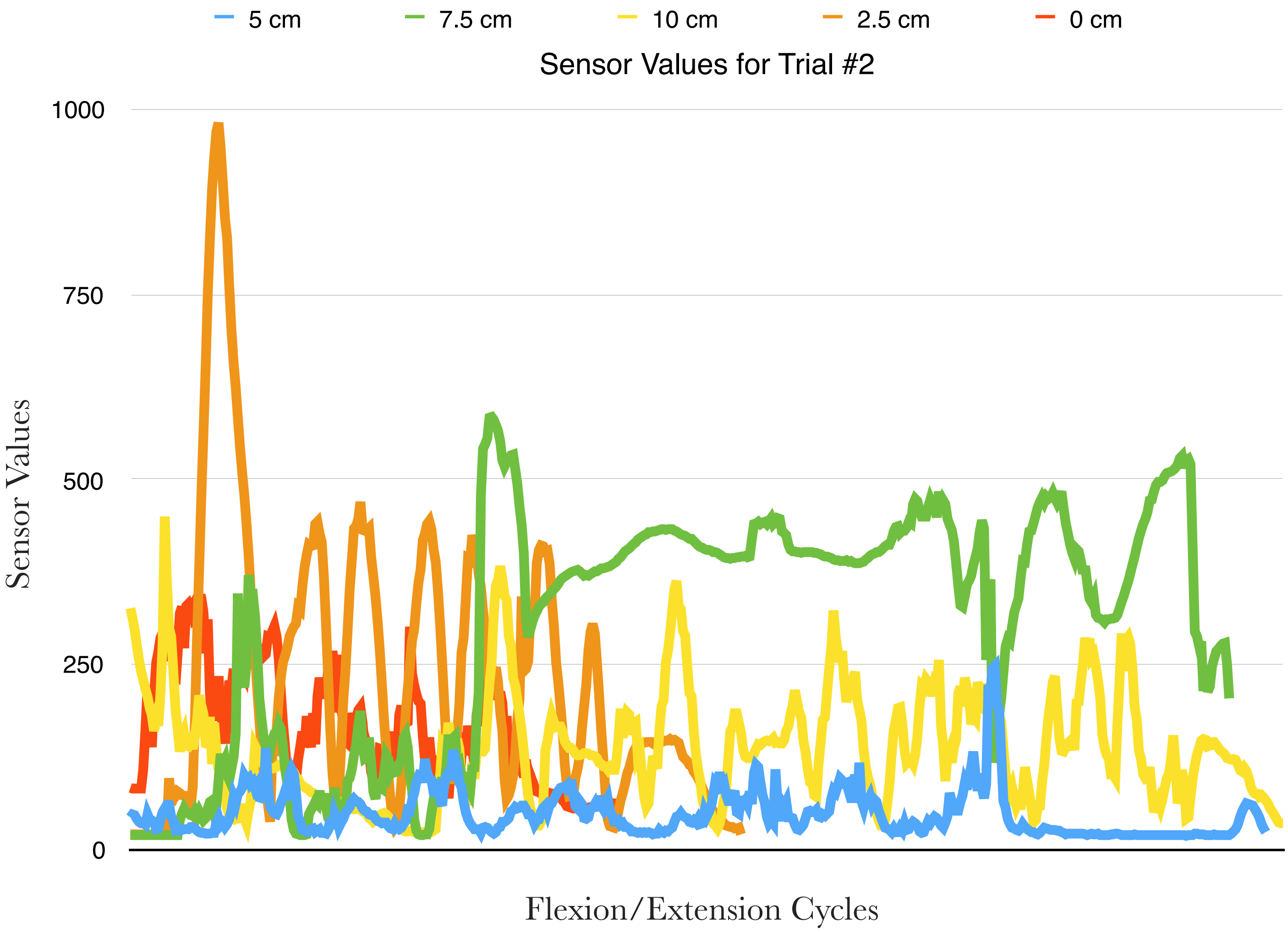
Values in each Location during Muscle Contraction						
		0 cm	**2.5 cm**	**5 cm**	**7.5 cm**	**10 cm**
Peak	**Peak #1**	324	420	98	111	183
	Peak #2	375	508	103	104	202
	Peak #3	410	262	67	132	190
	Peak #4	492	452	139	129	174
	Peak #5	182	904	77	149	144
	Average	356.6	509.2	96.8	125	178.6
Values	**Lowest**	18	19	32	19	18
	Highest	492	904	139	149	202

Trial #2

Values in each Location during Muscle Contraction		0 cm	2.5 cm	5 cm	7.5 cm	10 cm
Peak	Peak #1	341	983	137	371	450
	Peak #2	309	470	134	585	383
	Peak #3	268	444	108	433	363
	Peak #4	302	386	125	477	337
	Peak #5	280	147	248	534	286
	Average	300	486	150.4	480	363.8
Values	Lowest	54	20	18	19	22
	Highest	341	983	248	585	450

Mathematical Analysis





Analysis (Theoretical)

With every flexion/extension cycle, there are two peaks. Every time the muscle contracts, a sharp peak is first created in value, which dips down after, even if the muscle is held in place. This first peak is caused by the motor neuron signals to the muscle, commanding it to move. The second peak is most likely picked up from the tricep muscles that contract every time the elbow is extended. Since the tricep is further from the sensor, the signal is less intense.

It is clear that placing the sensor 2.5 cm away from the inner elbow gave the highest results, instead of placing it at 10 cm, where the belly of the muscle is. However, this may not apply to everyone, as people have different strengths, different amounts of overlying tissue, and their muscles could be more dense in different areas.

Unpredictable increases or decreases in value are most likely due to electronic disturbance which could have been outputted by nearby Wi-Fi signals, electronic devices, or even resistance in the wires. It is virtually impossible to eliminate these ambient signals.

Conclusion

The experimenter's hypothesis was not supported. The best position to place the sensor was not directly in the centre of the biceps, which would be at the 10 cm mark, as he expected it to be. The optimal position to place the sensor was 2.5 cm away from the inner elbow. The robotic arm moved accordingly and was the most responsive at this position, compared to other positions. Despite being outside the muscle belly, 2.5 cm still had the highest results. The experimenter could not determine a reason for this finding. Perhaps it had to do with the force required to flex the muscle during the experiment. The experimenter was only testing for the arm moving up and down, which did not require much force. The bicep muscles did not have to use as much motor units in this case. However, further experimentation is required to verify these results. The experimenter was unable to find another project that was similar to his, so there was not much to compare these unexpected results to, for a solid conclusion.

Global Application

Electromyography can be used as a controller for a prosthetic limb. Often, prosthetics can be manipulated by myoelectric means via electrodes, in a very similar fashion to how this project works. People who had their limbs amputated can use an electromyographic prosthetic limb to consciously control it. Prosthetic limbs such as this already exist, but they can still be calibrated and tweaked to become more sensitive and thus, move more smoothly. This project can also test the sensitivity of the sensor, as a diagnostic tool for doctors. They can use this data on a patient and diagnose neuromuscular diseases such as Lou Gehrig's disease.

Currently, the use of EMG for disease detection requires the means of a needle electrode. With further experimentation, perhaps the use of needles can become obsolete if the pad electrodes become more sensitive. This would benefit children who fear the use of needles. Apart from medical purposes, pastimes such as video games can implement the use of electromyography to create a controller powered by EMG sensors.

Errors

Since electronic disruption is very unpredictable, it is very easy to create bias when observing the results. It was not easy for the experimenter to find the exact amount of electrical activity in the muscles. Electrical interference could be picked up as ambient signals such as Wi-Fi signals or electrical outlets. Measurements were not always accurate.

The electrode pads became worn out over repeated use. This may have weakened the data in later experiments. Since the experimenter did not have an abundance of electrodes, he had to apply water to the underside of the electrode each time a procedure was done. This may improve sensitivity of the electrode, but it was nowhere as sensitive as when it was first unpacked.

Extension

A full robotic arm controlled by more servo motors can be attached to the sensor to further extend the potential of this project. More sensors and electrodes can be added to different muscles to create a fully functional robot. A video showing a side-by-side comparison with the muscle movement and values can further prove the correlation between the muscle and the values of the sensor. An extended version of this experiment can also include different subjects, strengths and muscles used.

Value Connection

One thing I needed to trust was my results. Patterns in the values suggested that the experiment was done correctly. I did multiple trials, each with similar results. This data will be very valuable in the future if it is applied to prosthetics, where amputees will need to trust these results to have the most responsiveness in their robotic limb.

Although further experimentation is required to verify the results, they seem plausible. Scientific reasoning in the analysis can ensure that the data is correct. I am truthful to say that my results did not match my hypothesis.

No living organisms were harmed in the process of this experiment. None of this data should be used for violence in the real world. I designed this project so that people can benefit from it, and not for people to harm others.

A controlled environment for each experimental procedure was made so that the results were not skewed and were fairly judged. I did not intentionally bias data to make my hypothesis correct.

Work Citation

Websites

YouTube. "MyoWare Servo Tutorial - EMG Arduino Circuit." YouTube. Google, 29 Jan. 2016. Web. 26 Jan. 2017. <https://www.youtube.com/watch?v=-JYi08WKe6c>.

"Electromyography." Wikipedia. Wikimedia Foundation, 10 Jan. 2017. Web. 31 Jan. 2017. <https://en.wikipedia.org/wiki/Electromyography>.

"Prosthesis." Wikipedia. Wikimedia Foundation, 05 Feb. 2017. Web. 05 Feb. 2017. <https://en.wikipedia.org/wiki/Prosthesis>.

Clements, Issac Perry. "How Prosthetic Limbs Work." HowStuffWorks Science. HowStuffWorks, n.d. Web. 05 Feb. 2017. <http://science.howstuffworks.com/prosthetic-limb.htm>.

"Electromyography (EMG)." Mayo Clinic. Mayo Foundation, 20 Jan. 2017. Web. 05 Feb. 2017. <http://www.mayoclinic.org/tests-procedures/emg/basics/definition/prc-20014183>.

Miller, Robert V., Jr. "ELECTROMYOGRAPHY—Uses and Limitations." California Medicine. U.S. National Library of Medicine, n.d. Web. 05 Feb. 2017. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1512376/>.

"The Role of Electromyography (EMG) in ALS." Massachusetts General Hospital. Massachusetts General Hospital, n.d. Web. 05 Feb. 2017. <http://www.massgeneral.org/als/patienteducation/ALSelectromyography.aspx>.

"Servo Library." Arduino. Arduino AG, n.d. Web. 05 Feb. 2017. <https://www.arduino.cc/en/Reference/Servo>.

"Motor unit recruitment." Wikipedia. Wikimedia Foundation, 29 Jan. 2017. Web. 02 Feb. 2017. <https://en.wikipedia.org/wiki/Motor_unit_recruitment>.

Books

Day, Scott. Bortec Biomedical. Important Factors in Surface EMG Measurement ed. Calgary: Bortec, n.d. Print. Bortec Biomedical.

Basmajian, John V., and De Luca Carlo J. Muscles alive: their functions revealed by electromyography. Vol. 2. Baltimore: Williams & Wilkins, 1985. Print.