Science Fair Lab Report

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Testable Question

1. **How does the accuracy and movement of robotic prosthetics (arms, legs, etc.) hold up to appendicular human limbs (Experimental)**

Creating robotic body part prosthetics (arm, leg, hand), after creating these we could theoretically demonstrate how these prosthetics can be controlled using the brain and specific nerves. We can demonstrate how the code will work and what it contains. This is important for people who have specific body parts cut off or non-functional.

How we can create safer or more efficient ways to deal or prevent COPD and other pulmonary diseases. (Research & Experimental)
Analysing antioxidants for cancer.

COPD stands for Chronic Obstructive Pulmonary Disease and revolves around lungs and windpipe. It is also responsible for bronchitis and emphysema, not only that, but it is considered to be one of the most deadly groups or types of disease. It is very likely in smokers as the tar from smoke can burn and chunk together hairs in the lungs that are responsible for moving mucus to the throat. This inflation can also result in a more narrow windpipe as a response, and side effects similar to those who have asthma may occur. We can potentially create a device that can pump oxygen into the heart and lungs. This project will talk about methods to prevent COPD and also how we can solve it.

- [ ] Add more components onto the highlighted sentence. (Go over each one such as how we will use servos and etc)
- [ ] how robotic hands are normally built (? Maybe do i'm not sure)

Research

Robotic prosthetics, also known as bionic or robotic limbs, are designed to replicate natural movement and provide enhanced functionality for individuals who had lost their limbs, such as their arm. The development and manufacturing of robotic prosthetics involve advanced technology and engineering. But how are robotic hands made in the first place? In the start, people often start out creating a human-like hand using a 3D printed plastic skeleton or bone structure of sorts, and also soft, moulded silicone material. Multiple sensors may be incorporated into the hand depending on if they only want to mimic functionality and movements, or if the manufacturer has plans to mimic other parts of the hand as well. For example, to mimic the way hands feel pressure, flexible pressure sensors are often applied to the hand's palm and fingers. This may also be used as of recently in modern technology and prevents objects from slipping out of grasp with just wrist movements. Making it so a lot of parts of the robotic hand don't have to be moved at once. Gyroscopes or Accelerometers may also be used to detect movement and positions. Finally, Electromyography sensors (EMG sensors) may be used to detect electrical signals from their muscles, which allows users to control the prosthetic based on their muscle activity. High-Strength, lightweight materials such as carbon fibre or titanium are commonly used as material for constructing robotic prosthetics. Though for 3d printing, materials like Nylon for its strength and flexibility, Resin for its high-resolution and smooth printing, Acrylonitrile butadiene styrene (ABS) for its durability and its impact-resistance, and also Polylactic Acid (PLA) for its biodegradability and also being lightweight. But one more, which is also the one we opted for, is PETG for its mechanical strength, thermal resistance, and is even more resilient and stronger than PLA. After the construction of the robotic prosthetic, it is often put through clinical trials and tests to see the liability, and functionality of the hand and if it really is fit to be used as a prosthetic.

<u>**(old research)**</u>

First of all, there are many different components of a robot prosthetic. This may include: elastic mechanisms (which may be similar to pulley mechanisms), servos, and circuits. As for the elastic mechanism itself, we are using strings attached to servos in order to create a pulley like mechanism that can not only bend the fingers, but also straighten them rather than leaving them bent. This is similar to the pulley as putting force can bend the finger, like a weight pulling down the string. The servos play a hand in this as they move the string itself to create the pulley like mechanism and move the fingers and hand , the servos attach to the string and play a big part in the movement of the hand. But how are modern day prosthetics built, and do they/what parts resemble the hand we built ourselves? In the start, people often start out creating a human-like hand using a 3D printed plastic skeleton or bone structure of sorts, and also soft, moulded silicone material. In order to mimic the way a human hand or skin feels pressure, flexible pressure sensors are often applied to the hand's palm and fingers. The build that has recently been starting to be used in modern technology prevents objects from slipping out of grasp or their hand with just wrist movements. Making it so a lot of parts of the robotic hand don't have to be moved at once. Modern day neuroprosthetics can be very expensive, heavy, and rigid, but new designs are being studied and made or in the process of being made that are cheaper, more lightweight, and give real time tactical control. These hands receive signals from Electromyography sensors (EMG sensors) which measure signals created by something called motor neurons which allow them to control muscles. These are often also including microprocessors and nerve impulses to run those motor drives. Finally, there are often pulley systems used to bend and straighten the fingers. Which was added to replace and play the role of the tendons in our hands. The hand itself reflects upon Newton's third law of motion, where it states "for every action (force) in nature there is an equal and opposite reaction. If object A exerts a force on object B, object B also exerts an equal and opposite force on object A. In other words, forces result from interactions." This principle is what guides the hand in a way when it comes to the pulley system or tendons, as we pull one string and put force, the finger bends, and pull the other to straighten the finger. This is a relationship with the string and finger, object A and B.

Principles

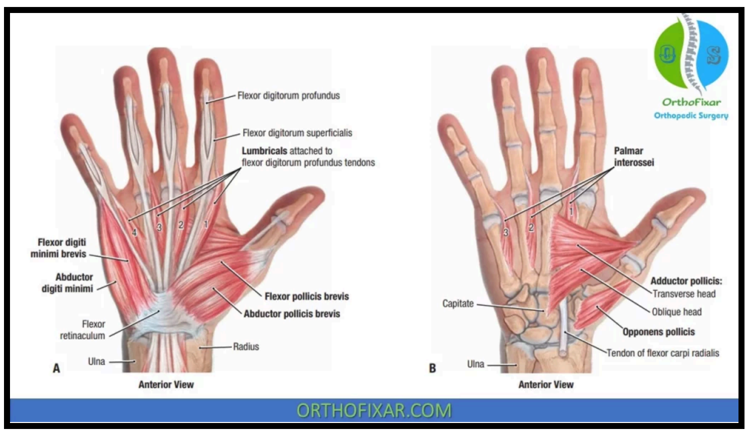
For our robotic prosthetic, we decided to do something reminiscent of a pulley system and flexor and extensor tendons to move our robotic hand. We will have strings throughout the palm and fingers which are attached to the servos and are thus able to move. The hand itself reflects Newton's third law of motion, where it states that **for every action (or force) in nature there is then an equal and opposite reaction that occurs.** If object A exerts a force onto object B, object B also exerts an equal and opposite force back onto object A. In other words, forces result from interactions. This principle is what guides the hand in a way when it comes to the pulley system or tendons, as we pull one string and put force, the finger bends, and pull the other to straighten the finger. This is a relationship with the string and finger, object A and B.

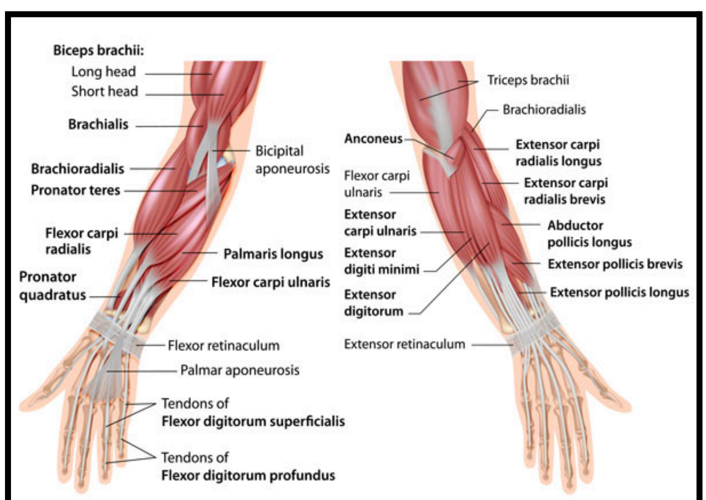
Testable Question

How Does The Accuracy of Robotic Prosthetics Hold up to Appendicular Human Limbs?

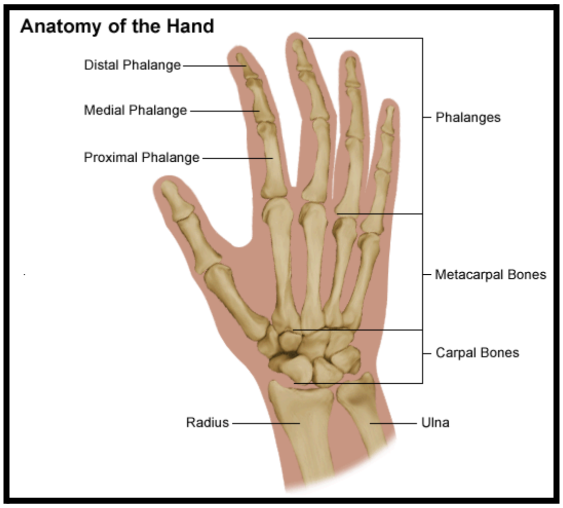
This project/experiment is aimed with the goal of seeing how accurate a robotic prosthetic can be to a normal human hand and also see how robotic prosthetics are made in the first place and if we can create one that is able to clench or grip objects with proficiency. We are also looking at how well and how long our hand can hold objects and what the robotic hand that is similar to our human hand. The entire idea is to see what needs to be improved upon in order to close that gap between accuracy of robotic prostheses and actual human limbs. Whether it could be because of texture, or size, or something else that resembles the anatomy of our hand and helps us grab objects efficiently. There are a multitude of different parts and features of a robotic hand that allows it to carry out specific functions. As the population grows, it is more probable and we are more likely to have amputees come to hospitals and other areas needing prosthetics to be able to live their life or at least do some things on their own. So in summary, **this project is aimed at looking at and taking a deep dive into the manufacturing of robotic prosthetics**, and to see if we can create a robotic prosthetic that is able to grip objects and bend/straighten its fingers properly.

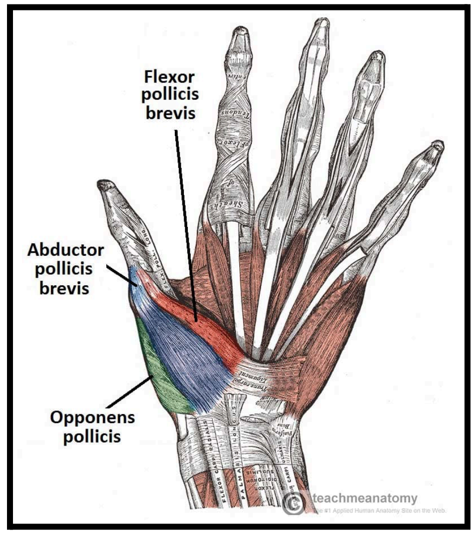
<u>Anatomy of our forearm and hand:</u>



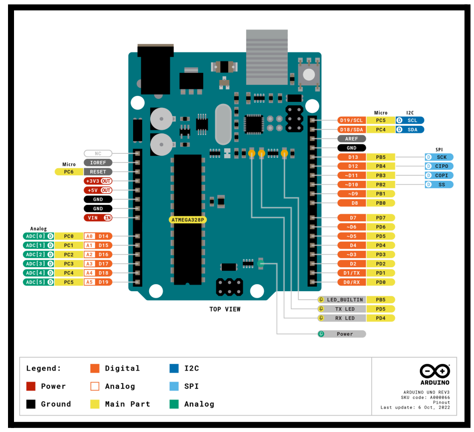


The hand is composed of many different types of bones, muscles, and ligaments that allow for a large amount of movement and dexterity. Your wrist is the joint at the end of your forearm. It acts as a hinge between your arm and hand that lets you reposition your hand. Tendons are flexible pieces of tissue that connect bones to muscles. There are two types of tendons: flexor and extensor. These allow for multiple different movements of the hand or joints, such as flexion, extension, and hyperextension. Flexor Tendons run from the forearm and go all the way to the ends of our fingers on the palm side of the hand which gives the ability to bend fingers and make things such as a fist or pinch objects. There is also flexion, flexion is when you bend a joint and the angle of that joint is then decreased. Extensor tendons run underneath the skin alongside the back of your hand and wrist and they control the hand's ability to straighten your fingers and wrists. This can be compared to a pulley system of sorts that allows fingers to be bent or straightened depending on the strain of movement force. These tendons are held in place by the band of the tissue, otherwise known as the retinaculum. The bones that make up hands are the carpal bones, metacarpal bones, and Phalanges which make up the hands bone structure. The Carpal bones and Metacarpal bones make up the palm of the hand, while the Phalanges make up the fingers. There are three bones which can be distinguished by looking at the space from the palm to the knuckle, and that knuckle to the next knuckle, and so on. The three phalanges that make up each finger are called the Distal Phalange, Medial Phalange, and Proximal Phalange respectively in a top to bottom order. These altogether create the bone structure of your hands. The bones in the forearm connecting to the wrist and hand are the Radius and Ulna. There are also three muscles called the thenar that arch toward the thumb called the Flexor Pollicis Brevis, Abductor Pollicis Brevis, and the Opponens Pollicis. These are some of the most important muscles in the hand and allow one of the most important functions of the hand, which is to hold or grasp objects as the Abductor Pollicis Brevis pulls away the thumb from the hand and the Flexor Pollicis Brevis move it toward the little or pinky finger. The Opponens Pollicis opposes the thumb and keeps it in that place to allow it to completely stay farther from the index finger and grasp objects.





Tech:



Pinout: The Arduino Uno has 4 types of power pins, the VIN, 5v, 3v3, and GND. The VIN is used to power the Arduino board using an external power source. The 5v and 3v3 pins provide regulated voltage to power external components. Finally, the GND (ground) pins are used to close the electrical circuit and provide a common logic reference level throughout the circuit. There are 6 analog pins, labelled from A0 to A5. These pins can read the signal from an analog sensor and convert it into a digital value that we can read. 7 Digital pins, which can be used for both digital input and digital output. PWM is a technique used to encode a message into a pulsing signal. They are composed of 2 components: frequency and duty cycle. PWM frequency dictates how long it takes to complete a single cycle and how quickly it fluctuates from high to low. The cycle determines how long a signal stays high out of the total period. Finally, Serial, Serial communication is used to receive and transmit data between the Arduino board and another serial device.

Hypothesis

If the prosthetic is going to mainly be compared in areas of movement and grip, **then it** will likely not be able to hold objects as efficiently as a regular hand **as** the structural integrity/design of the build and texture of a prosthetic normally being more bare with less functions and also being harder to replicate.

This is especially applicable to the grip sector of this experiment, as you need the thumb to be far enough from the hand to grasp objects but still be flexible enough to wrap around the object and touch the other fingers to hold it tight. Also another process that may be difficult is having the 3 phalanges bend individually so it can wrap around the object enough to be held properly and stabilised by the fingertips.

the fingertips.

Variables

Controlled Variable: The controlled variables for each trial would be the size of each prosthetic and the materials used for the grip and the rest of the hand.

Manipulated Variable: The manipulated variable is the dimensions and shape of the object needed to be held.

Responding Variable: How well a robotic prosthetic can grip and hold certain objects.

Uncontrolled Variable: After multiple usages, the material and prosthetic may not be as smooth and efficient compared to when it was originally created.

Materials

- **9 volt Battery Holder**
  - We will be using this to power or prosthetic. This 9 volt battery holder will be able to power our prosthetic effectively and efficiently without running out of power.

- **PCA9685 16 channel PWM Servo Motor Driver**
  - This is what will connect our Servos to the Arduino. This 16 channel Servo Driver will be able to connect our 5 motors freely, making it easier to connect to the Arduino without putting much load on it.

- **Arduino Uno R3**
  - The Arduino Uno will be our microcontroller for this prosthetic. This is because of its easy connectivity to other components, and its simple and accessible user experience.

- **5x Miuzei 9G Servo Motors**
  - These servers are used to pull on the Flexor and Extensor String system. We chose these because of its cost effectiveness and 1.8 kg torque.

- **<u>Mckanty Clear Nylon String</u>**
  - This string is used to extend and contract our fingers. Its high tensile strength and thin diameter is exactly what we need.

- **<u>3d Printer</u>**
  - The 3d printer was a main part of our project. This allows us to create our prosthetic online, and create it with different types of plastic. Overall, it is much easier to create instead of creating it ourselves with household materials.

- **<u>Black PETG filament</u>**
  - This is the filament we used to print our prosthetic. PETG is a thermoplastic polyester commonly used in manufacturing. We chose PETG because it is known to be stronger and more resilient than other filaments.

- **<u>5x Servo Motor Pulleys</u>**
  - We decided to use a pulley system for two main reasons:
    - The first being that, when we want to open and close the fingers, the strings will work in reverse, allowing the action to be made easier.
    - Secondly, it would be much easier to connect the strings to, and using the original tops would take much longer to set up.
- **<u>2-3mm Elastic Bands</u>**

- **<u>Gauge Electrical Wires</u>**

<u>Procedure</u>

1) Open up the Arduino IDE software and install our libraries. Because we are coding the PCA9685 servo driver first, I will install the AdaFruit Servo Driver Library. This allows the PWM sequence to be installed into our circuit, without having to code it ourselves.

```
#include <Wire.h>
#include <Adafruit_PWMServoDriver.h>
```

2) The next step is to define the minimum and maximum pulse length for our servos.

```
#define SERVOMIN 150
#define SERVOMAX 600
```

3) Next, define how many servo motors we will be using.

```
uint8_t servonum = 0;
uint8_t numberOfServos = 6;
```

4) Now, I will be controlling the amount of steps the servo will take. I will start from 0 degrees (SERVOMIN) and go to 180 degrees (SERVOMAX). Now I need to move it back to 0 degrees. I will create a delay so it isn't an instant movement, and then I will start from SERVOMAX and go to SERVOMIN.

```
void loop() {
  for (uint16_t pulselen = SERVOMIN; pulselen < SERVOMAX; pulselen++){
    myServo.setPWM(servonum, 0, pulselen);
  }
  delay(500);
  for (uint16_t pulselen = SERVOMAX; pulselen > SERVOMIN; pulselen--){
    myServo.setPWM(servonum, 0, pulselen);
  }
```

5) The final step would be to test our code with the servos, we did this multiple times until we were sure everything was working properly.

Movement Code

```
#include <Wire.h>
#include <Adafruit_PWMServoDriver.h>

Adafruit_PWMServoDriver myServo = Adafruit_PWMServoDriver();
```

```
#define SERVOMIN 150
#define SERVOMAX 600

uint8_t servonum = 0;
uint8_t numberOfServos = 5;

void setup() {
  Serial.begin(9600);
  myServo.begin();
  myServo.setPWMFreq(60);
  delay(10);
}

void loop() {
  for (uint16_t pulselen = SERVOMIN; pulselen < SERVOMAX;
pulselen++){
    myServo.setPWM(servonum, 0, pulselen);
  }
  delay(500);
  for (uint16_t pulselen = SERVOMAX; pulselen > SERVOMIN;
pulselen--){
    myServo.setPWM(servonum, 0, pulselen);
  }
  delay(500);

  servonum ++;
  if (servonum > numberOfServos-1)
     servonum = 0;
}
```

Grip Code

```
#include <Wire.h>
#include <Adafruit_PWMServoDriver.h>

Adafruit_PWMServoDriver myServo = Adafruit_PWMServoDriver();
```

```
#define SERVOMIN 150
#define SERVOMAX 600

uint8_t servonum = 0;
uint8_t numberOfServos = 5;

void setup() {
Serial.begin(9600);
myServo.begin();
myServo.setPWMFreq(60);
delay(10);
}

void loop() {
for (uint16_t pulselen = SERVOMAX; pulselen > SERVOMIN; pulselen--) {
myServo.setPWM(0, 0, pulselen);
myServo.setPWM(1, 0, pulselen);
myServo.setPWM(2, 0, pulselen);
myServo.setPWM(3, 0, pulselen);
myServo.setPWM(4, 0, pulselen);
}
delay(500);

for (uint16_t pulselen = SERVOMIN; pulselen < SERVOMAX; pulselen++)
{
myServo.setPWM(0, 0, pulselen);
myServo.setPWM(1, 0, pulselen);
myServo.setPWM(2, 0, pulselen);
myServo.setPWM(3, 0, pulselen);
myServo.setPWM(4, 0, pulselen);
}
delay(500);

servonum ++;
if (servonum > numberOfServos - 1)
servonum = 0;
}
```

1) After brainstorming on how we wanted the prosthetic to work, we implemented our thoughts onto our modelling software tinkercad, which is an online modelling software which allows for advanced models even with basic principles and is an intermediate software friendly to those who have prior knowledge on modelling. During this process, we purchased all of the materials.

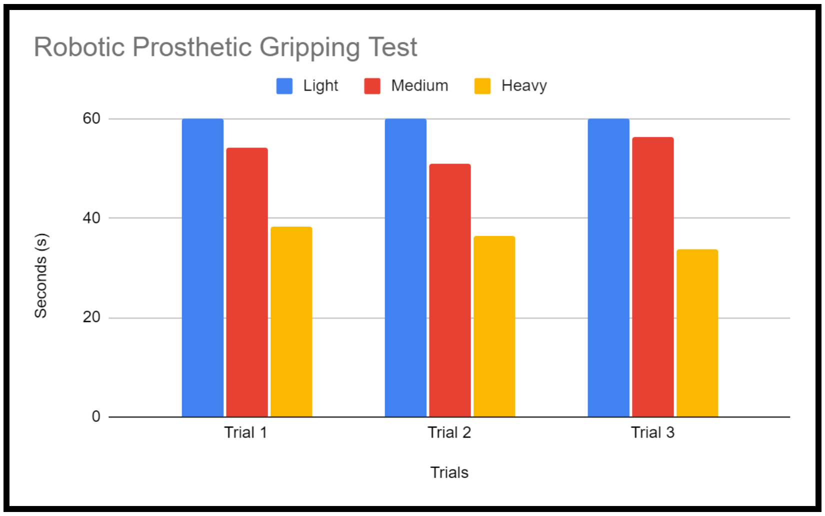
2) Once the model was completed, we printed it locally from a 3d printing service.
   - When the model was received, we had to construct it.
     - First, we had to join the finger together. We put the elastic bands in the hole, and created tension with an aluminium rod.
     - Next, we tied string on the back and front of the fingers, feeding it through the holes in the palm to our servo pulley system.
     - We attached the strings to each of the pulleys, and repeated this process for the other fingers.

3) Now, after constructing the prosthetic, we will conduct our experiment. During the three trials, we will focus on 2 main criteria:
   - Mobility
   - Grip

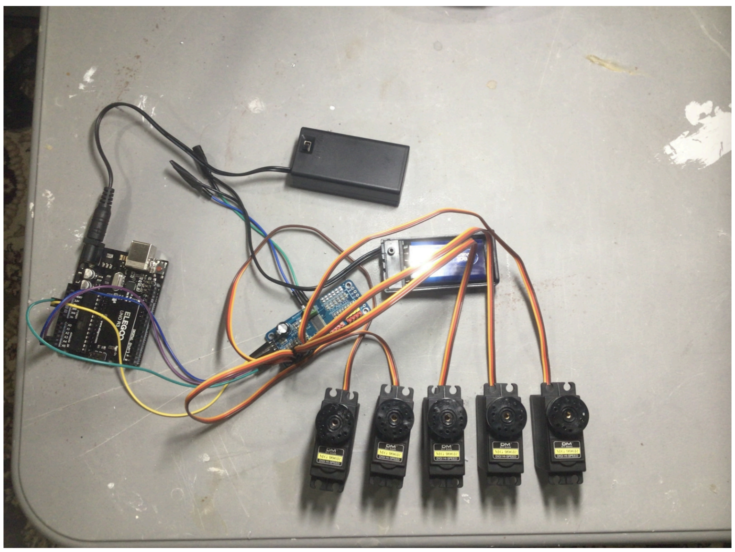
This was done during the course of the 3 trials. Once completed, we will collect our data and compare it to a human hand. This data will then be used to create our final conclusion.

Results & Observations

Trials	Light	Medium	Heavy
Trial 1	60	54.2	38.4
Trial 2	60	50.9	36.3
Trial 3	60	56.3	33.7



Some things I observed in this experiment were that as it was holding the object, it would eventually start to slowly lose its grip. For example, though it could hold the **Light & Small** object toward the **60 second limit with ease** and likely for much longer, when it held the **Medium & Moderate** object **it tended to lose its grip around the 45-50 second mark.** The same thing happened with the **Heavy & Large** object, it began to lose its grip around the **30-35 second mark**. It then quickly lost its grip and the object had dropped for every other Medium and Heavy object trial. The reason it loses grip is comparable to gripping a basketball or other spherical object with your hand, it's not only about the ability to grip well itself, but also mainly having large enough hands to hold the ball comfortably and having large enough fingers to not lose grip or tire out as fast. In conclusion, our robotic hand demonstrated the ability to grip onto both small to large objects for an extended period of time, however the robotic hand did not exceed the abilities of a human hand due to the limited amount of movement and functions. Though, being large was not as much of a problem for our new hand, but more so how slippery the hand seemed, especially the fingertips. For the human graph, it constantly held for the maximum amount of time/limit that was applied, 60 seconds. This is because the human hand had a better grip on the object, and the fingers were somewhat thinner, and also longer to wrap around the objects.



Conclusion

Overall this experiment was a success in some ways, though we made many mistakes that limit the hands potential and ability, we still created a working hand that could grasp specific objects comfortably and could easily move its fingers. Our hypothesis was right as a hand could hold crumpled paper, an apple, or a metal water bottle for much longer with less degree of difficulty then the robotic hand would. Though it works it is still somewhat rigid and can't hold many objects for a long time. This is seen with the Heavy & Large objects and trials especially.

Sources Of Error

There were a lot of unprecedented errors that had come up with our experiment.

- One large oversight was the thumb, all fingers could comfortably bend and straighten. But the thumb could not rotate to grab cylindrical objects such as water bottles.

- This was a huge oversight and held the hand back quite a bit because it could not wrap around objects and was held back in use quite a bit because of it. Instead of rotating it would just be blocked by the object.

- Another was that we only had two phalanges that could bend, and not three, so the fingertips/distal phalanges were rigid and did not have much leeway to properly grasp objects.

- The grasp was awkward and stuck. When you grab a water bottle, you are bending your distal phalanges. But when you grab something thin like paper or a dollar bill, your distal phalanges are bent less and are more flat. So because we did not have control over the bending of the distal phalanges, some objects could not be grabbed efficiently.

Applications

People may be interested in our results and project as it reflects on amputees and their daily struggles. Studies and efforts to not only improve quality of life but also increase the efficiency of robotic prosthetics and alleviate pain or uncomfort has only recently arisen. Before, many prosthetic limbs were based on use, not comfort, or giving the ability to feel things such as pressure on your hand, or heat. For hands especially, moving fingers or wrists could be tough with a prosthetic hand and tiring as they would have to tense up in a way in order for the electromyographic sensors (EMG sensor) and such to move hands, but recently electroencephalographic sensors (EEG sensors) have been beginning to replace electromyographic sensors (EMG sensors). There are lots of amputees, whether it was from an accident, an external source or weather conditions such as frostbite, or something else. Many people are in need of prosthetics, and robotic prosthetics not only allow them to regain crucial abilities that will help them in their life and re-establish parts of their body.

Next Experiment

For our next experiment, or next time, I would focus more on addressing the shortcomings of our robotic prosthetic hand to further enhance its functionality as a hand. While our previous design showed promise, it also revealed several limitations that hindered its full potential as a working hand. We encountered many problems that held the robotic prosthetic back from its true potential and efficiency as a hand. I will also try to make it larger in the sense it comes with a forearm to hold the circuits, wires, and batteries. This forearm can also allow wrist movements and allow more rotations for the hand to comfortably hold objects with ease, even if the object is uniquely shaped or has a texture/material that increases the difficulty of holding it. The length of the fingers was also a large oversight as stated before, so I would fix the fingers in the sense that they are longer in size in order for the fingers to find a way to grab the object more effortlessly and for a longer time before tiring out. These changes can help close the gap between the functionality, accuracy, and grip strength of our robotic hand, and a real human hand in the world of robotics prosthetics.

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