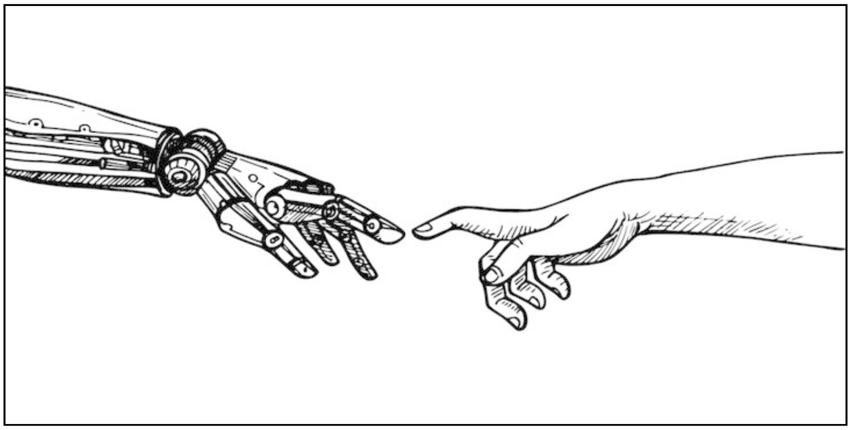
Hand-in-Hand

Name	NetID	Section
Arnav Sheth	amsheth2	ECE 120
Wyatt Wethington	wyattlw2	ECE 120
Adnan Challawala	adnanmc2	ECE 110



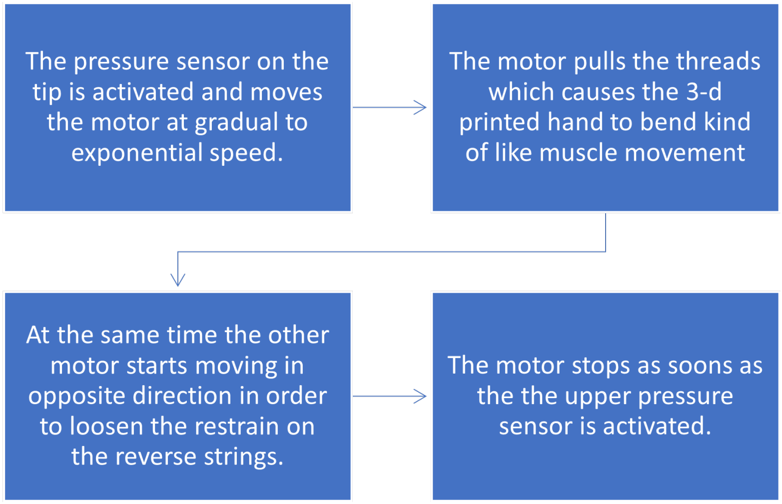
Statement of purpose

We wish to use our knowledge of electronics and digital logic to create a bionic hand which helps in strengthening the force of the hand for those who are affected with muscular disorder where the person can't grip on stuff that he is trying to hold or move his hand effectively with a complete range of motion. T he project is designed to create a basis for a cheap, highly useful device that those suffering from neuromuscular disorders can utilize in order to return working human functions to them.

Background

Our project was born as an offshoot of a type of VR glove that incorporated haptic feedback, and we later decided that this idea was stronger. The hand is currently designed for those with neuromuscular control issues - “Currently there is no cure for neuromuscular disorders. Research is being done on genetic therapies and new medications in hopes of finding a cure. Treating symptoms, delaying disease progression and enhancing quality of life for patients is accomplished with medications, physical therapy, occupational therapy and, when necessary, surgery”. Neuromuscular disorders, while they cannot be cured presently, the patients can definitely be given another chance by bionics, so we have decided to bring our knowledge of ECE to enhance the hands of those in need. We also looked into haptic feedback VR suit, bridge builder, 8-bit calculator, etc. and are a few of many ideas thought, however we felt that those projects had already been done or they never helped humanity, so we thought as deep into our brains as we could to uncover from our mind the idea of a bionic hand which helps people use their motor functions perfectly. Our project is expected to incorporate many types of subfields since bionics is a diverse field for ECE: power electronics, digital logic, PCB design, 3D design, microcontroller/FPGA-type control of devices, programming, biology and physics.

Design Details



Parts

Component	Website/Procurement Location	Purpose	Quantity	Cost ($)
A 3D printer with reels (Preferably white)	N/A, located in CITL armory space	Hand model creation	1	0
Servos	Inventory https://www.adafruit.com/product/154 (example)	Regulation of RPM	will order 1 from inventory initially	~4 from inventory
Pressure Sensors	https://www.digikey.com/en/products/detail/dfrobot/SEN0295/10136550	Controlling when to change RPM	will order 1 initially	6.90 per unit
Silk Thread	https://www.wawak.com/Thread/Thread-By-Weight/Medium/gutermann-silk-buttonhole-thread-tex-30?sku=GTDV800&gclid=Cj0KCQjw1ouKBhC5ARIsAHXNMI8mvuglitJALROMacgvjCXePb4UMfzgKtvNUfvLBm9OpcJHsyzdiKwaAnkWEALw_wcB	Act of providing enhanced grip strength to the user	1 roll	2.99 per roll
ADALM Module + ECE 120 Kit (breadboard + associated parts)	https://www.walmart.com/ip/24-Pack-LR44-AG13-SR44-357-303-LR44G-Battery-Ultra-Power-Premium-Alkaline-1-5-Volt-Non-Rechargeable-Round-Button-Cell-Batteries-Watches-Clocks-Electr/852682837	Power + Current regulation	1	0
Arduino UNO kit	Using personally owned UNO	Digital logic, acts as a mechanism for control of the hand	1	0
~~DC-DC Converter or similar current control device~~ Current regulation will be performed with ADALM	~~May design our own PCB using KiCad or similar software. If not then might purchase, should be fairly small~~ ~~Example of what we will be using:~~ ~~https://www.digikey.com/en/products/detail/texas-instruments/TPSM84205EAB/7561620~~	~~Current regulation for RPM control~~	~~will order 1 initially, if ordering~~	~~4-8 per pcb~~

Potential Challenges

~~1.) To control RPM we will need to control the current levels. Our idea is to control the RPM of the stepper motor through a DC-DC converter circuit or a current regulator type device. Due to cheap converter circuits being on PCBs this presents an area issue if we follow through with using PCBs to control current~~ No longer matters as of 09/30

2.) Placement of any batteries and motors with respect to the hand, at the time of writing still thinking about optimal arrangement and area concerns

3.) 3D design of a realistic hand model. We expect the mechanical aspect of this project to be by far the most challenging part. We also are expecting to have to make our own CAD file or build upon an existing file to print the hand design, both of which require 3D design

4.) Physics of the hand model, particularly the strings and rotational motion, quite challenging. We will research these areas and cite resources used in learning below

References

[1] “Myasthenia gravis fact sheet,” *National Institute of Neurological Disorders and Stroke*. [Online]. Available: https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Fact-Sheets/Myasthenia-Gravis-Fact-Sheet

[2] “Articles,” *Cedars*. [Online]. Available: https://www.cedars-sinai.org/health-library/diseases-and-conditions/n/neuromuscular-disorders.html

[3] “Types of muscular dystrophy and neuromuscular diseases,” *Johns Hopkins Medicine*. [Online]. Available: https://www.hopkinsmedicine.org/health/conditions-and-diseases/types-of-muscular-dystrophy-and-neuromuscular-diseases

[4] “Build an artificial hand,” *Scientific American*, 14-Jan-2016. [Online]. Available: https://www.scientificamerican.com/article/build-an-artificial-hand/ (article's design for rotational motion is incredibly similar to ours)

[5] “Exo-suit (part 3: Gauntlets) by Roman13,” *Thingiverse*. [Online]. Available: https://www.thingiverse.com/thing:1982745 (base hand model, link contains STL files)

Updates

(09/30): Replaced stepper motors with servos on parts list; will purchase from inventory. Replaced batteries with ADALM module + breadboard materials on parts list in order to provide power and manage balance. Implementation of ADALM also removes need for a DC-DC converter as ADALM is inherently capable of current regulation. Breadboard will assist in providing power

(10/14): First 3D printout of the design has been made. The hand is functionally complete and would suffice for the project's purpose but after examining the model for endurance capabilities the durability of the hand over the course of the semester is questionable. We are taking precautions for experimentation in the future and considering alternatives to the current material + design

Servo + pressure sensor simulations are being run using the UNO kit and progress on the electrical subsystem is being made concurrently with progress on the hand design. Going to implement the servo motors by arraying them on a wrist plate that is separate from the hand, preferable to attach them using a strong adhesive substance such as glue dots. The servo was successfully implemented during trials with the UNO kit + pressure sensor and we expect to have the electrical subsystem complete soon. Currently working with only 5 analog input pins which may need to be addressed in the future

(10/21): Beginning to initiate the closing-motion stage of the hand design, using 5 servo motors. Could use hot glue on the hand design in order to maintain structural integrity throughout the semester

(11/4): Going to start the hot glue process today or at least attempt to get it started to make the rest of development smoother, need to start from scratch with the hand pieces which may take some time. We think that we have the rest of the design completed; for the uncurling motion of the hand, we are strongly thinking about implementing a spring system in the wristplate in order to rapidly uncurl the hand. Not sure how feasible this will actually be during implementation, but it would save us from using more servo motors and pressure sensors since only one pressure sensor would be necessary in order to activate the spring system. Would hopefully be cheaper as well

(11/11): Hand design is practically fully assembled and bonded together with glue, moving on to implementing control mechanisms assuming no setbacks. Moving forward using servo motors for the opening motion; we have plenty of servos available and we already have 10 pressure sensors available on hand

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Final Report

Demo: https://drive.google.com/file/d/1h7hAG0XOyuWZuKoVqTj18Yrbjk1hwryP/view?usp=sharing

Introduction

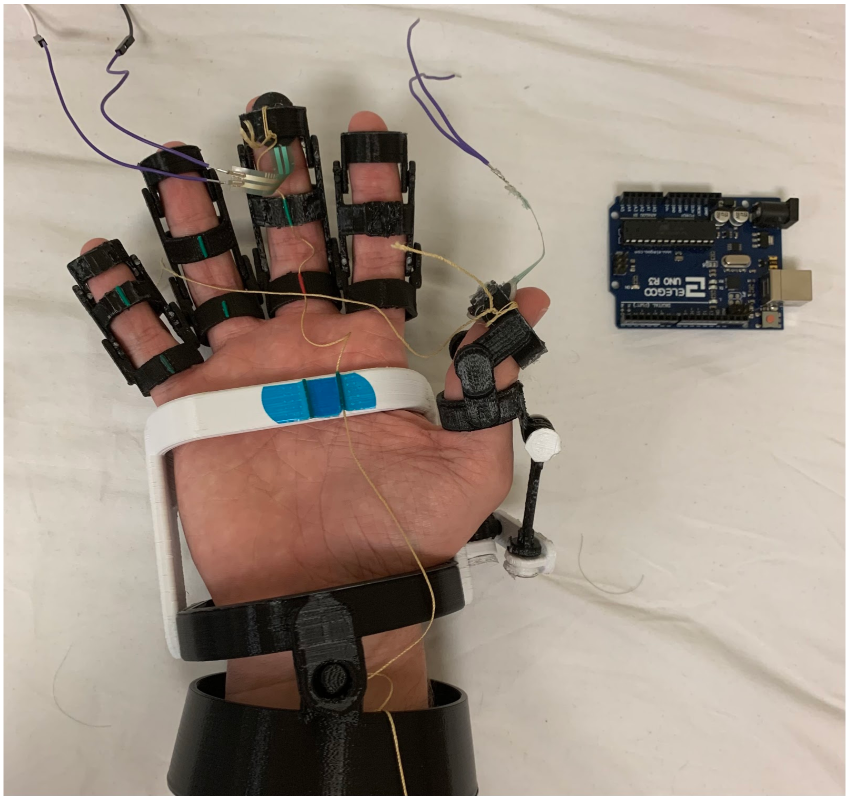
Statement of Purpose

We felt very strongly that attempting to make a project capable of helping people would be the most enjoyable to accomplish, and we decided that learning how to mold and program an exoskeleton would be the focus of our project. Our project is currently designed for those with neuromuscular control issues, and is optimized for those with some, but not full, muscular control in their hand. Neuromuscular disorders can be remedied with technology, and we decided to create something capable of providing an enhancement for people suffering from these conditions. Our project incorporated applications from quite a few different fields, including: power electronics, digital logic, 3D design, microcontroller/FPGA-type control of devices, programming, biology and physics.

Features and Benefits

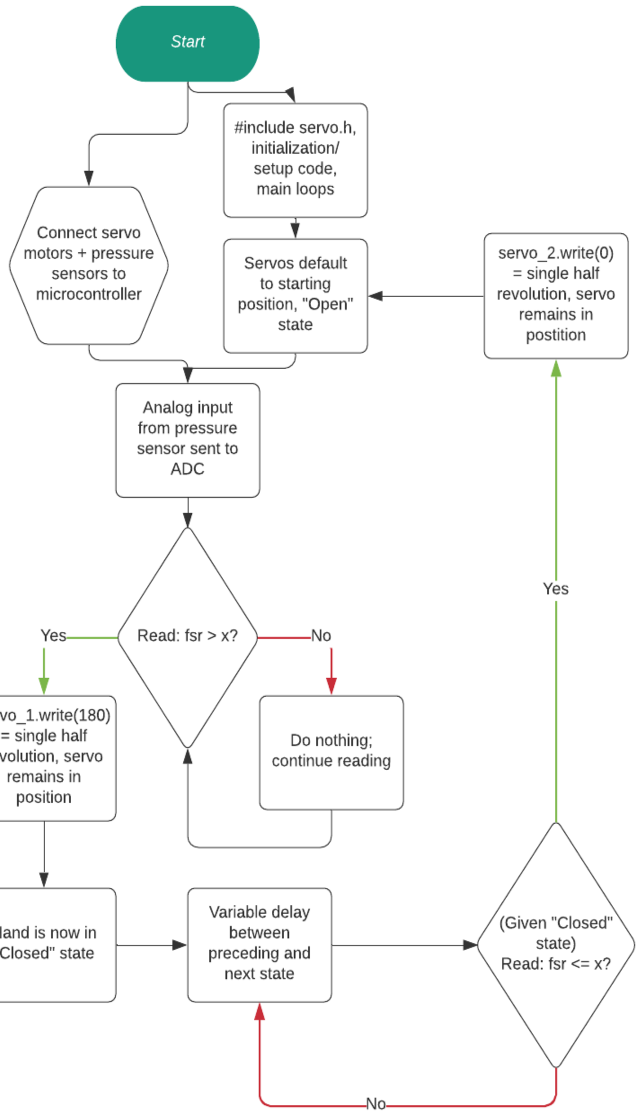
The exoskeleton operates using a pressure-based detection method and an actuator system placed near the bottom of the wrist that grants motional functionality to the exoskeleton. The system was carefully designed so that a single servo motor would be sufficient for the entire hand to close. This is also enabled by the careful threading beneath/above the fingers that redirects the force in a pattern that was chosen to support tendon motion in a real human hand. The model is capable of semi-automated closing and opening motion, and is strong enough to grip surfaces in several different applications.

(an older work-in-progress version of the model is below)



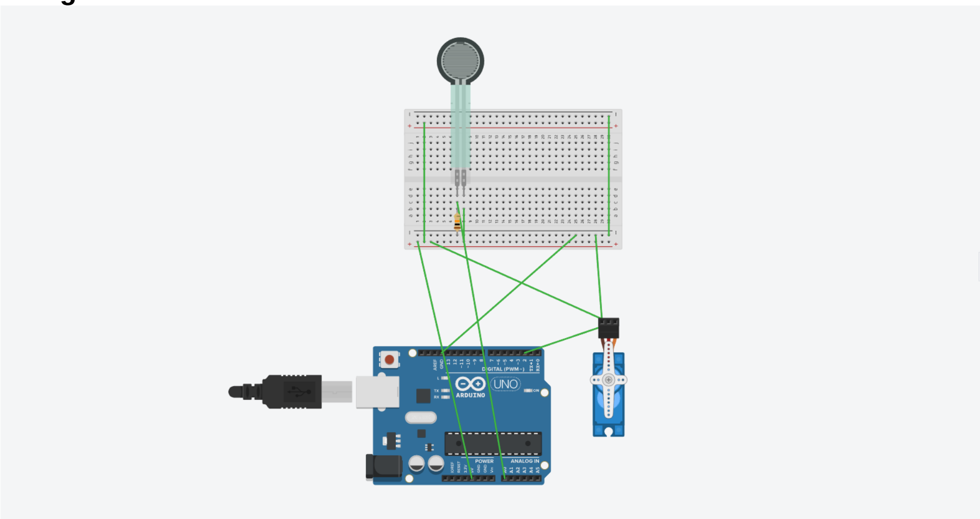
Design

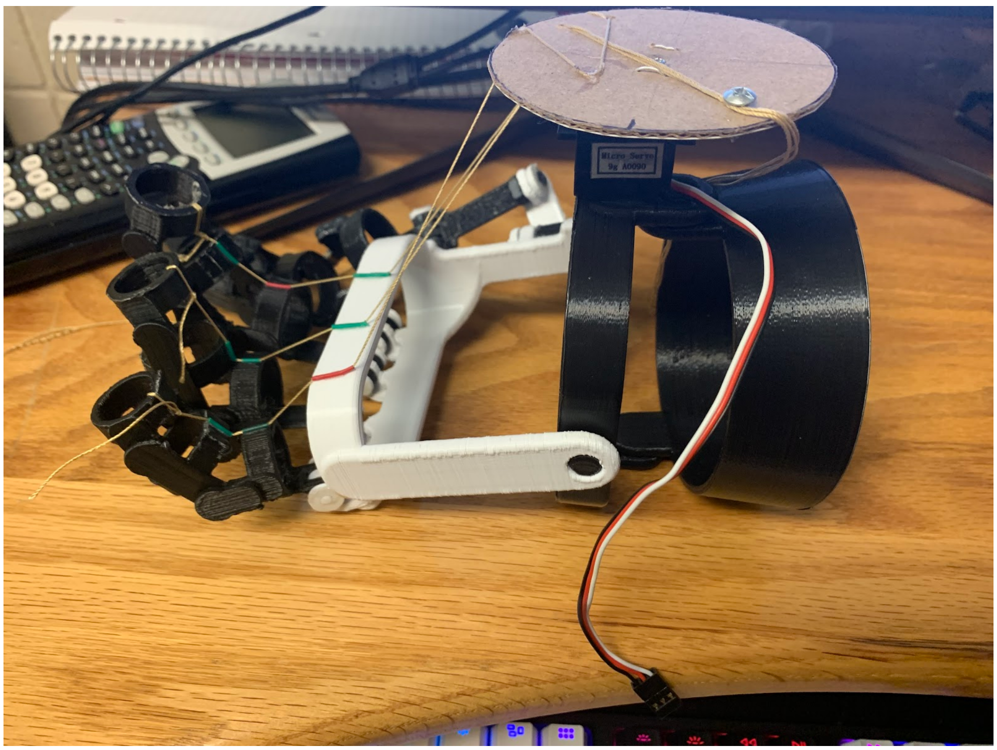
System Overview



The above flowchart is a combination of the hardware and software systems acting together. Data collected from the pressure sensor(s) is converted into a digital signal and is used to determine whether the servos should be active or not active. If the digital value is read to be above or below the specified integer, a servo will activate which will result in the actuator system causing the exoskeleton to either close or open. The digital values for the variable fsr have a range between 0 and 1023; for our project's design, we are using an fsr value of around 150, making the system quite a bit sensitive to pressure. For the system, there are two states "Open" and "Closed".

Design Details





Our design came down to the 3D printed model, which was thankfully able to be primarily based on an existing STL file for a different project (https://www.thingiverse.com/thing:1982745, credits to Roman13). The hand has not been printed for a specific fit but has been made sufficiently large enough to fit most hand sizes. The structure of the hand was used in order to place a threading system along the base of the fingers, and a very well placed system of wire sheaths redirects the threads in a way that when tugged on will move the finger in the same fashion as tendons would. A pressure sensor has been attached to the interior index finger of the exoskeleton (not visible in the picture above) that reads for applied pressure from the user and determines if the actuator system should activate. The actuator system is visible near the wrist of the hand and supports the motion of the fingers using a servo; the servo rotates the disc slightly less than 180 degrees and causes the hand to close. Note that in order for the hand to open we have implemented the same threading system above but for the reverse side; we are using a second servo to open the hand, but as of the current time of writing we do not have a functioning second servo and are momentarily leaving it off. Also note that there are no sheaths on the index finger of the exoskeleton - the index finger will not be connected to the actuator for making demoing a simpler task. Additionally, the motion of the rest of the fingers is sufficient for grip to be obtained. The breadboard was simply used to connect the components to the microcontroller and a basic overview is visible above. The logic gate requirement of the project is accomplished by just switching out a few of the parts.

servo_executable | Arduino 1.8.16

File Edit Sketch Tools Help

servo_executable §

```
// C++ code

#include servo.h

int fsr = 0;

int a = 0;

Servo servo_1;

void setup()
{
    pinMode(A0, INPUT);
    Serial.begin(9600);

    servo_1.attach(2, 500, 2500);


}


void loop()
{
    fsr = analogRead(A0);
    Serial.println(fsr);
    if (fsr > 700)  {
      servo_1.write(360);
    } else {
      servo_1.write(0);
    }
    delay(10); // Delay will likely be made longer for demoing purposes
}
```

The code for this project was very simple thanks to the availability of servo libraries on the Arduino. It also allowed us to skip a lot of the math in this project. As seen above, beyond the setup code there is a loop that checks for pressure and sends a signal to servo_1 if successful. This is not our final code and is merely example code as a few things are different or missing in this picture.

Results

In our eyes, the project is definitely successful. The hand is capable of gripping onto things while being worn by the user and mimics human motion incredibly well. Especially given the net cost of the parts in the final product (I think around $20-$30 maybe? Ignoring the UNO) we are somewhat satisfied with the project's progress. We are saying "somewhat" because there are huge consistency issues with the pressure sensors we bought and used, and also because the 3D model can cause some discomfort when worn. We also realized that incorporating friction pads onto the fingers would improve the project's functionality and we would have liked to revise the project for that purpose. Outside of those factors, we are pretty excited with the final product.

Future Plans

We've discussed several possibilities for the future and we are very, very strongly thinking about creating an entirely new detection method for the exoskeleton. It would incorporate tendons immediately on the wrist and might involve machine learning in order to measure very minor tendon activation, which would vastly improve the functionality of the hand. We also would like to incorporate more software into our projects, regardless of which directions the projects take.

Appendix / References

[1] “Myasthenia gravis fact sheet,” National Institute of Neurological Disorders and Stroke. [Online]. Available: https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Fact-Sheets/Myasthenia-Gravis-Fact-Sheet

[2] “Articles,” Cedars. [Online]. Available: https://www.cedars-sinai.org/health-library/diseases-and-conditions/n/neuromuscular-disorders.html

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