OVERVIEW

1. Building the exoskeleton
    a. 2023 Summer Break
2. Exoskeleton version 1
    a. 2023 Summer Break
    b. 2024 Winter/Spring
3. Exoskeleton version 2
    a. 2024 Summer Break
4. Testing exoskeleton version 2 on an individual with hypotonia
    a. 2025 Winter/Spring
    b. *Informed Consent Form is attached at the end of this logbook*

2023 Summer Break

Day 1: 2023-07-26
I bought an existing exoskeleton online and took it apart to modify the design

Learned y = map (x, 0, 1023, 0, 90) (just an example)

- It can convert one set of measurements to another after you put in the minimum and maximum of both sets

```
void loop() {
  Blinker.run ();
  x = digitalRead (2);
    a = analogRead (A1);
  Serial.println (a);
  b= map (a, 0, 1023, 0, 255);
  c = map (b, 0, 255, 0, 180);
  d = 180 - c;
```

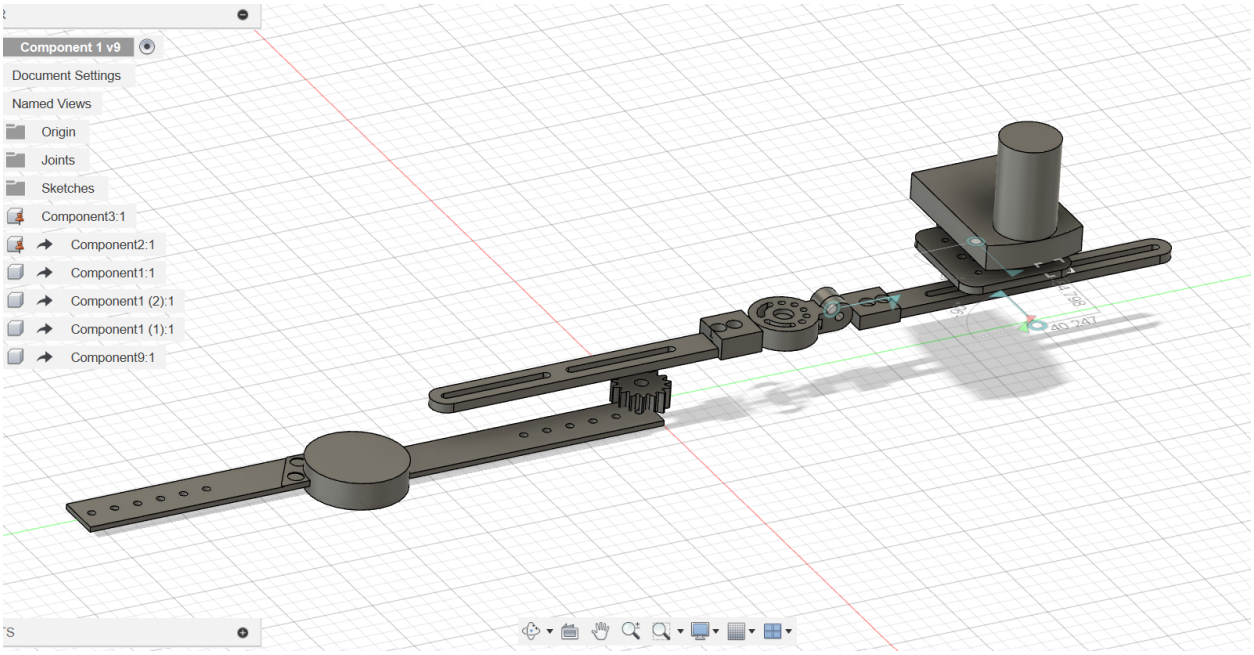
The screenshot on the left is an example of how I used the code. I converted the potentiometer's ADC values of 0-1023 to 0-180 degrees.

I plan to spend the next few days learning more skills that will help me complete my project. Because I plan to use an existing exoskeleton and then attach steering motors and other components that are programmed, I need to research and get more familiar with these materials.

Day 2: 2023/07/27
I started to build a tiny model of the exoskeleton to program the steering motors. I constructed the model from wood, imitating the structure of human thighs and calves. I then attached small steering motors to places where the wood pieces connected (the motors acted as joints). The process was pretty tricky because I had to program the model so that it could imitate a person walking. It was hard to imagine a normal walking process and then translate that to code. I did

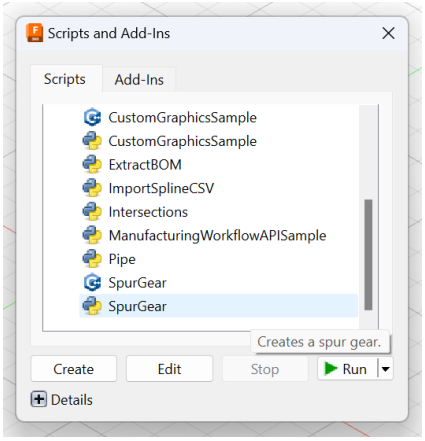
not finish coding on this day so I knew I had to continue with trial and error multiple times in the following days.

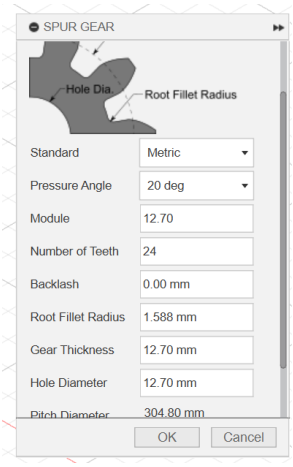
Apart from creating this model, I started to sketch out the main structure of the exoskeleton I bought in Fusion 360. Although it was a very tedious and complicated process, I believe that it will help me significantly when it comes to deciding where and how I want to place the gears, steering motors, straps, etc. I learned how to




Day 3: 2023/07/28
Learned how to quickly draw gears in Fusion360 and related concepts

- Shift+S → Choose the Spur Gear Python module
- Teeth number (z), module (m), hole diameter



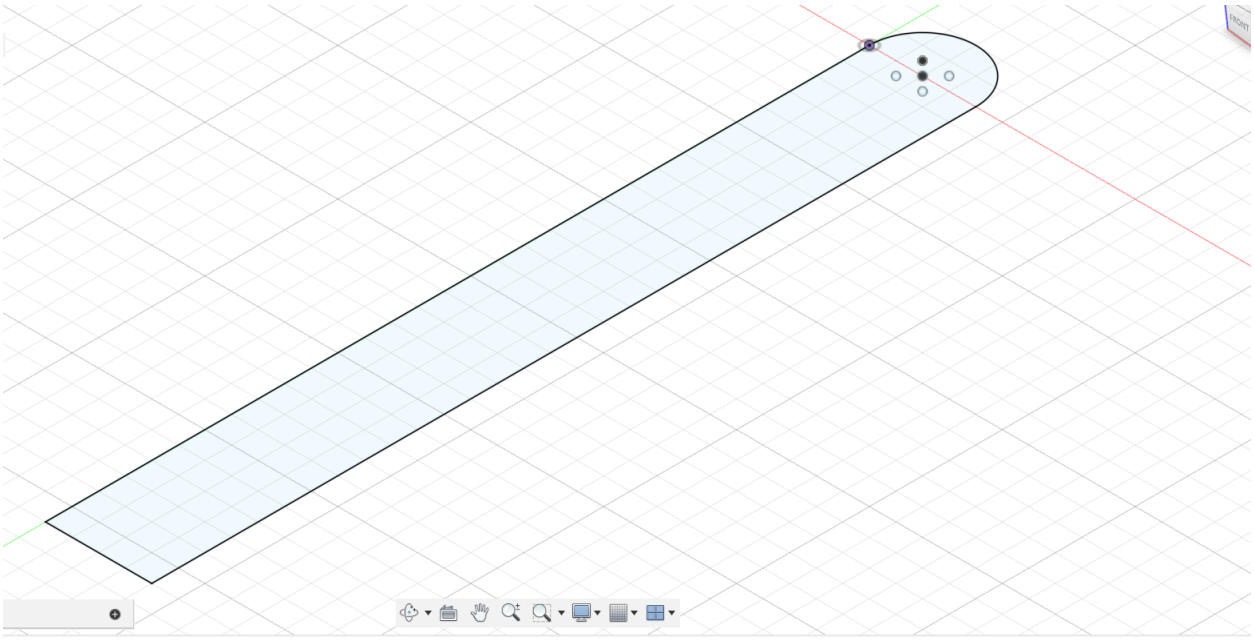




I needed to learn how to draw gears because the steering motor would be attached to a pair of gears, allowing the exoskeleton to work. This combination of components would serve as the joint of the metal legs. Drawing a gear by hand would be too time consuming (I'll have to spend hours learning how and then actually designing it) and it could result in inaccuracies.

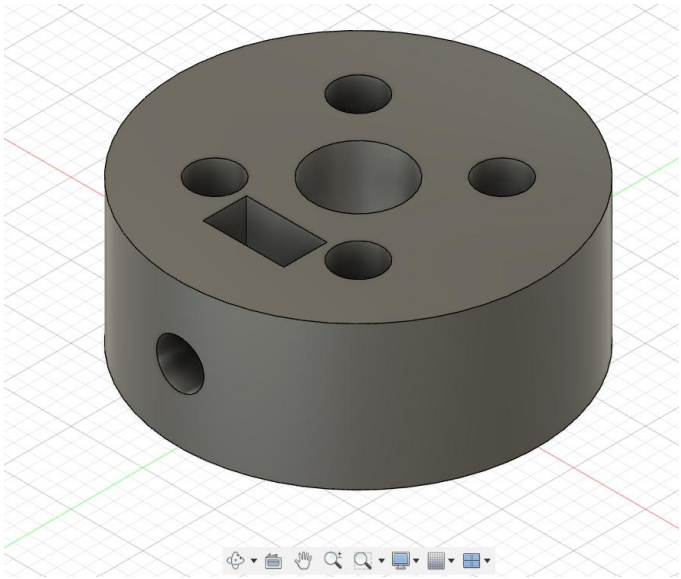
Day 4: 2023/08/01

1. Design components for data collection and testing

a. AutoCAD: 3 wooden panels will be attached to the leg using adhesive straps. Panels will be laser-cut



b. Fusion360: 3D component that attaches a tracker and the 3 panels together. This component will be placed where my joints are so that the wooden panels can rotate freely as my legs move.

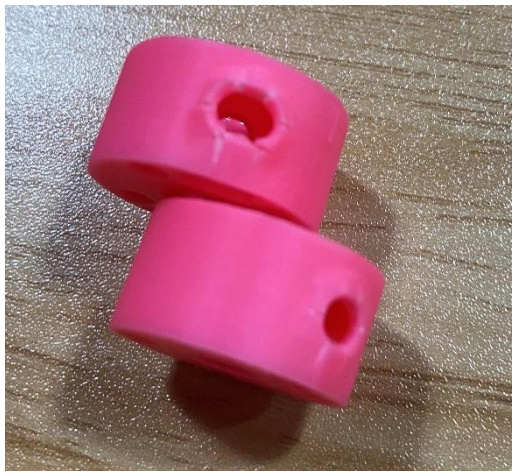


2. Write code for tracker using -90°, 0°, and 90° as benchmark degrees

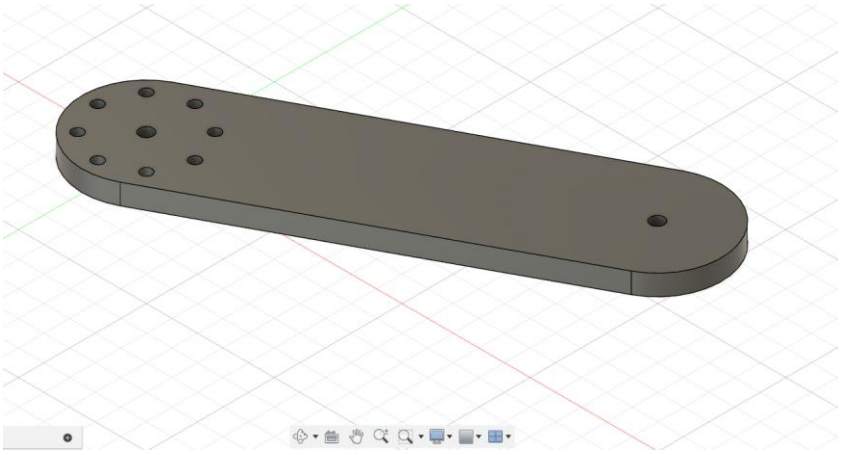
This data collection model will help me determine what degrees I should set the steering motor to. After I complete this model, I will wear it around my legs and walk naturally to record the degrees of my joints' movements.

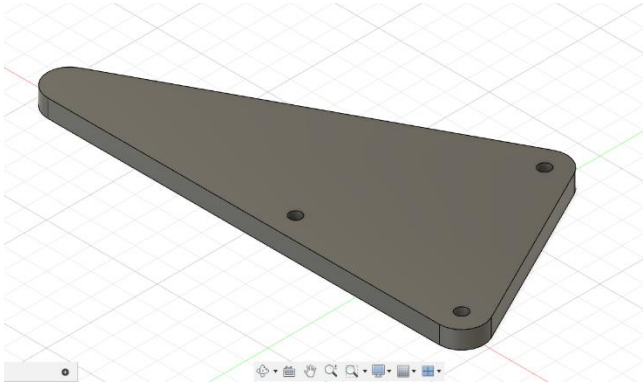
Day 5: 2023/08/02

Lots of trial and error as I started the data collection process and continued with my designs. For example, the cylinder attachment piece I designed and printed yesterday started to break apart after I screwed it tightly to the wooden panel because the diameter was too small. Thus, I had to increase its thickness so it wouldn't break so easily.

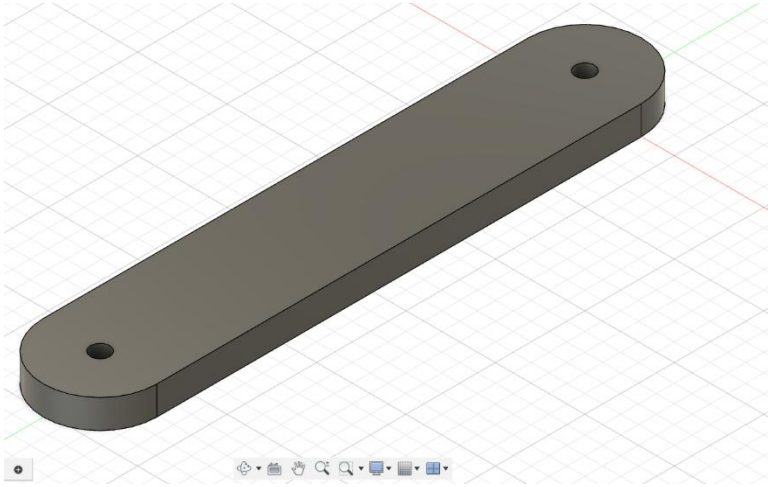


- Designed two components to attach the servo and gear to the metal leg part of the exoskeleton. They will be cut from an acrylic board and form a parallelogram.





- Printed another acrylic piece to connect the two components I created earlier.



Started data collection but couldn't copy the data from Arduino's Serial Monitor

- I downloaded an older version of Arduino (1.8.15), but I still had trouble copying all the data
- Finally, I found CSV → added to "tools" → upload the code → click ArduSpreadsheet → save the data → open it in Microsoft Excel

Day 6: 2023/08/03

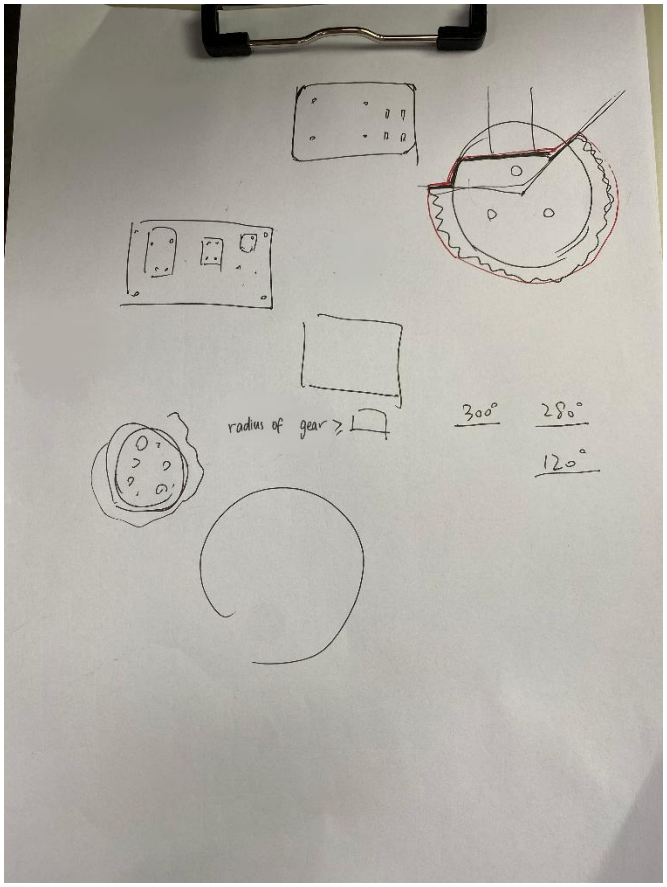
I changed the length of one of the parallelogram components from 83.853 mm to 147.50 mm.

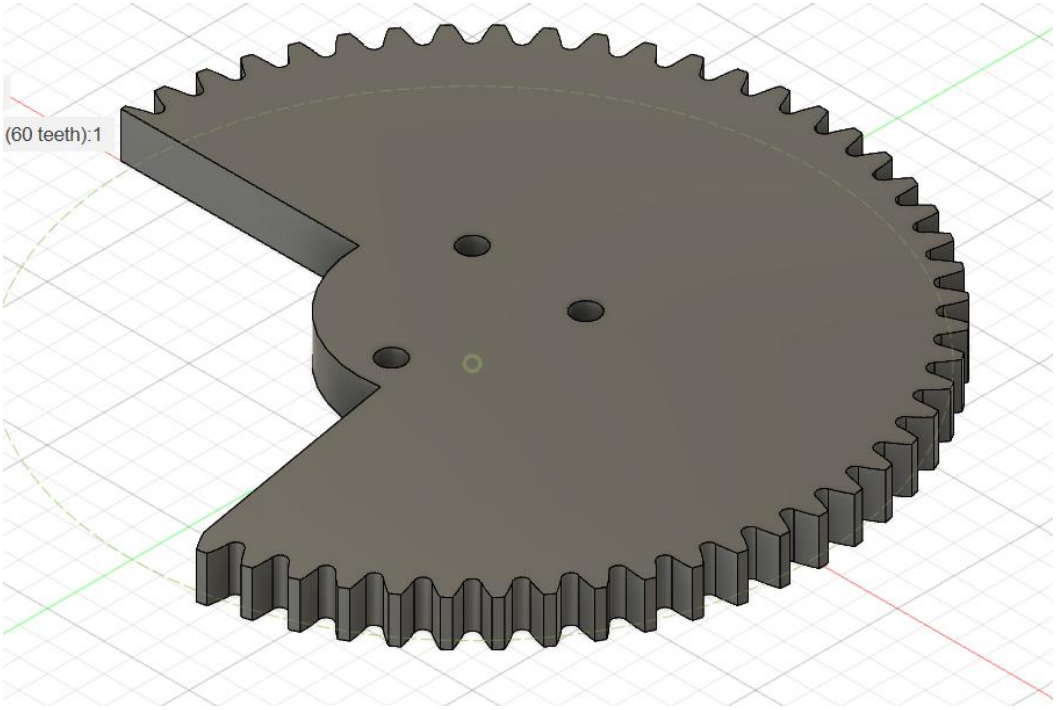
Now that I learned how to copy down the data from Arduino's Serial Monitor thanks to yesterday's efforts, I started to collect the data using the model I built previously (see DAY 10 and 11). The picture below shows the results for the right leg. After I finish testing and see the data in Arduino's Serial Monitor, I export them into an Excel file. It's incredibly useful that the ArduSpreadsheet included timestamps to indicate when my joints hit the indicated degrees. The middle column, which shows less change between each movement, is the data from the upper tracker placed at my hip joint. Thus, the right-most column shows information for my right knee.

| | | |
|---|---|---|
| 05:14.5 | -7 | 20 |
| 05:14.5 | -7 | 20 |
| 05:14.5 | -7 | 21 |
| 05:14.5 | -7 | 20 |
| 05:14.5 | -7 | 20 |
| 05:14.5 | -7 | 20 |
| 05:14.5 | -6 | 20 |
| 05:14.6 | -6 | 20 |
| 05:14.6 | -6 | 20 |
| 05:14.6 | -5 | 20 |
| 05:14.6 | -5 | 20 |
| 05:14.6 | -5 | 19 |
| 05:14.6 | -5 | 19 |
| 05:14.6 | -5 | 19 |
| 05:14.6 | -4 | 19 |
| 05:14.6 | -4 | 19 |
| 05:14.6 | -4 | 19 |
| 05:14.6 | -4 | 19 |
| 05:14.6 | -4 | 19 |
| 05:14.6 | -3 | 19 |
| 05:14.6 | -3 | 20 |
| 05:14.7 | -3 | 19 |

Day 7: 2023/08/04

Planned and designed the gears located at the thigh, connected to the bars that link the waist and thigh together using the method I learned on 7/28.



Assembled said gears with the metal bars and servo

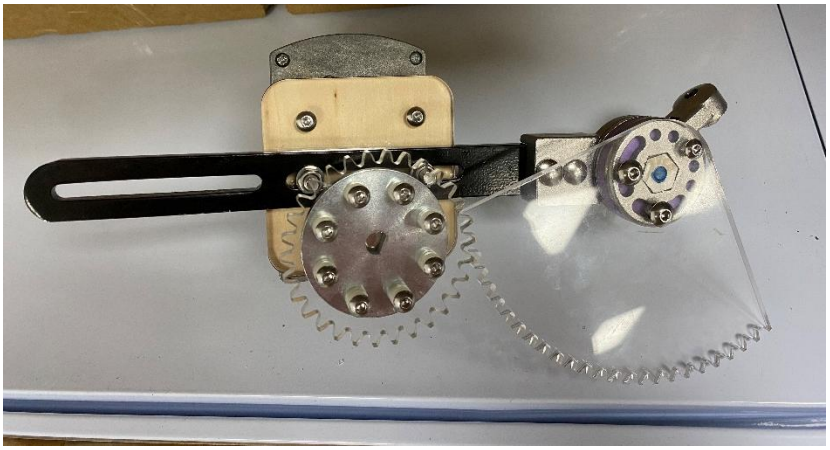
The metal bars kept slipping and moving around even after screwing them together because I changed the placement of these bars to suit my design. Therefore, I designed and printed a 3D component to put in between the attachment places and add more friction.

DAY 8

2023-08-05

I ensured that I had all the necessary components prepared, and I promptly printed the ones that were missing from my setup. While waiting for the 3D printers to finish, I continued with my data collection process, ensuring a seamless and efficient workflow.

I also combined the gears I designed and laser-cut yesterday with the Servo steering motor. This metal bar would connect the thigh component to the waist, and the cut-out gear would serve as the hip joint of the exoskeleton.



I also assembled the other metal bar with another Servo, the 3D-printed connecting square, and the laser-cut acrylic parallelogram combination. This silver, thicker metal bar would be placed next to the user’s calf.

DAY 9

2023-08-06

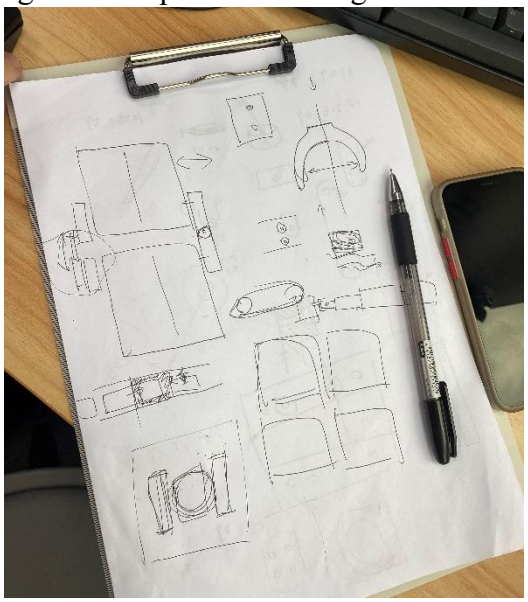
Finally started to assemble the parts I've been designing and building over the past week. I started with the hip area. I had to 3D print out the smaller gear because the acrylic board I laser cut it on was too thin for my liking. 8 cm → 9 cm.

DAY 10

2023-08-08

Continued to assemble (attach thigh/hip black metal bar to the waist support thing)

Designed and printed the part that connects the gears to the user's leg. C-shape. Has a slot to pull an adhesive nylon strap through and wrap around the leg.



Started to solder the wires.

Thought about the impact of this project

- My grandfather fell during early spring, which reminded me that the elderly doesn’t have that much leg strength. Using a cane or a walking stroller thingy doesn't guarantee walking support because if you have weak arms, you'll still fall. Also causes their spinal cords to bend. My project has a high-waisted structure that can also provide spinal and waist support. Customizable leg straps allow people with all kinds of body types to use them.

Day 11 2023-08-09
Finished printing all 6 C-shape leg attachments

Got rid of the Lower Calf C Attachment

Inserted adhesive nylon straps

Changed Triangular Connection Part (added more holes so I could connect the Upper Calf C Attachment)

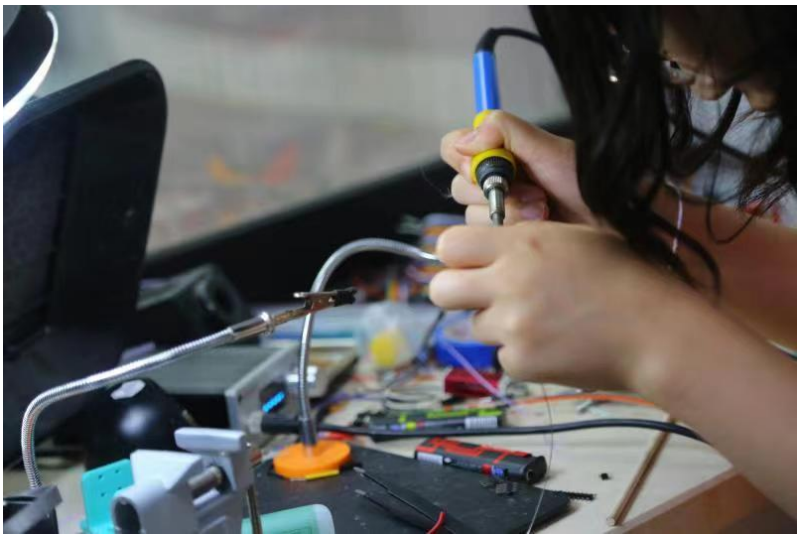
Designed and laser cut new components (check 3mm and 5mm thingy, a component the teacher modified from Aluminum and Gear Part Connection)

Removed the Connecting Square (see DAY 14 8/5, where I assembled it with the silver metal bar)

Added aluminum bars

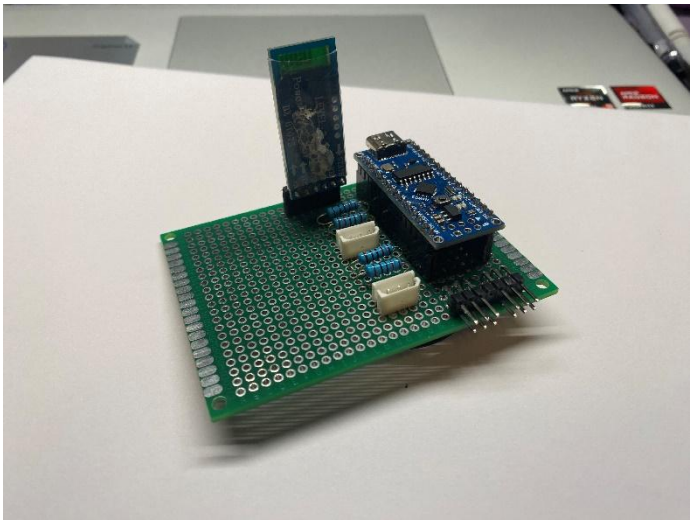
Fixed some mistakes (e.g. one of the gears and one of the metal bars were put in the wrong/opposite face)

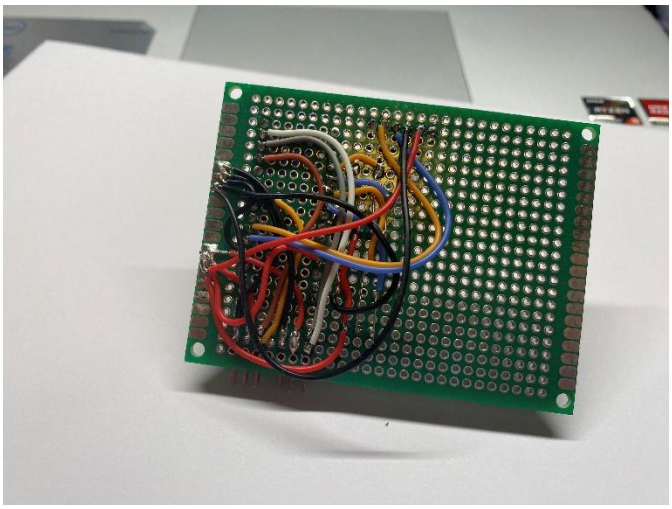
Started assembling cables and pressure sensors and connecting them to the gears and continued with bonding the wires.



I used an Arduino Nano board and attached it to a protoboard. Apart from setting up the outlets for the pressure sensors and Servo steering motors, I also inserted a Bluetooth module, which allows me to use the app Blinker to start and stop the exoskeleton’s movements.

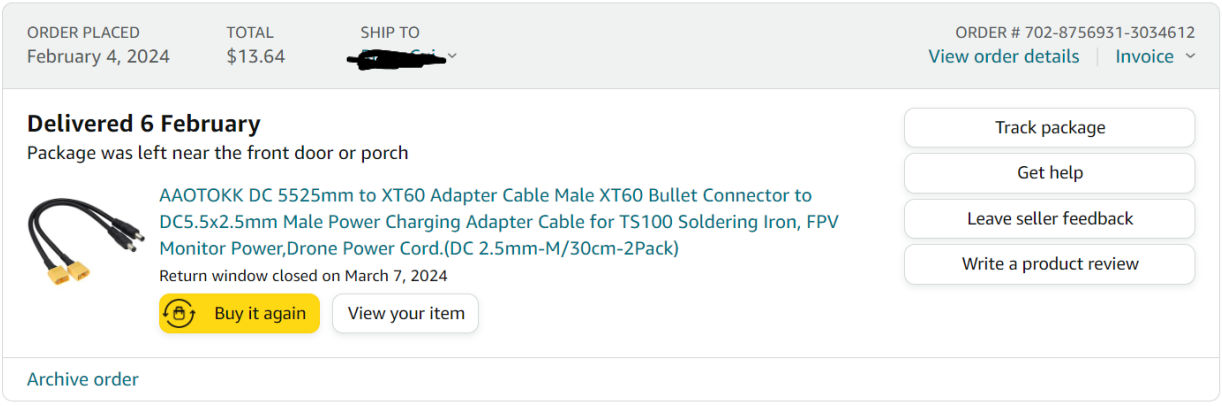
The picture at the left below shows one side of the protoboard with the Nano board, Bluetooth modules, and other outlets. The photo at the right shows the other side, which has all of the wires/cables I connected.





Day 12 2024-02-04

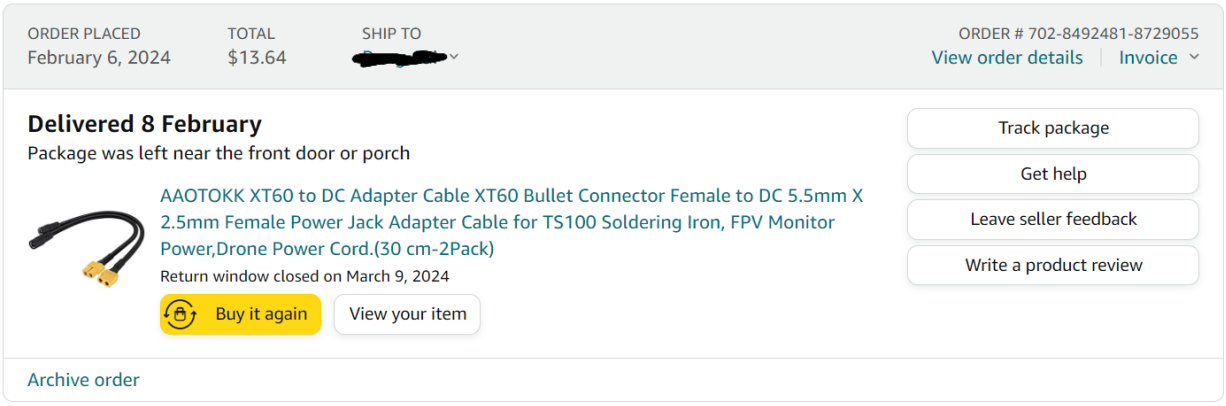
After taking a break from this project (I still did a little bit of work and research every day, but the progress of a single day was too little to document. Most of this project's work was accumulative), I resumed my progress by first ordering an adapter cable to connect my Servos to a 12V lithium-ion battery.




I continued to use the data collection device while intentionally walking with different gaits to collect data for later use.

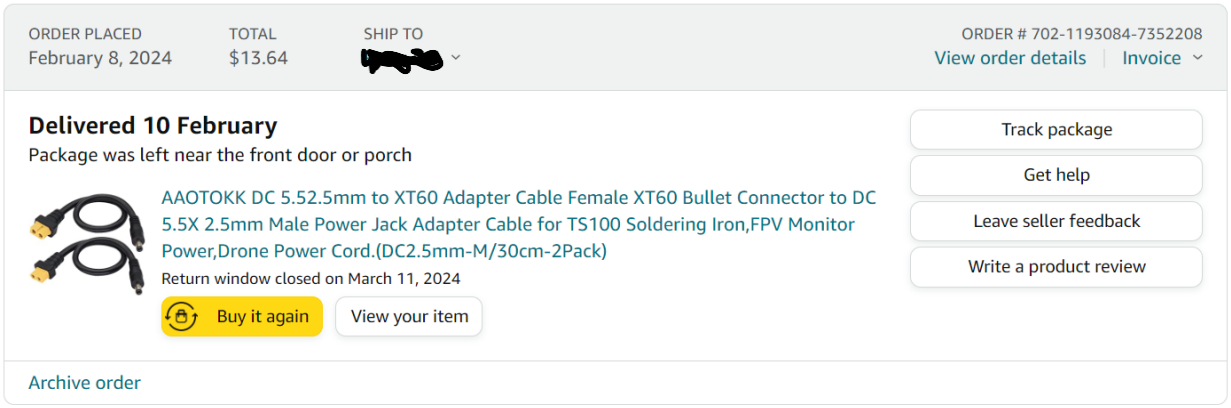
Day 13 2024-02-06

After receiving my previous order, I discovered that I had purchased the wrong model. The head connecting to the Servo wires should be a female XT60 connector. I placed another order.




Day 14 2024-02-8

Although I got the XT60 connector type correct in my last order, I accidentally chose the female power jack adapter instead of the male. I placed another order.




Day 15 2024-02-10

I finally received the correct power cord with the correct connector models. I started uploading my codes to the four Servos. Since today was a Saturday, I had enough time to experiment with the Servos' rotational movements and made sure they matched my different gaits. Although it was a very tedious process, I essentially repeated the same steps: test exoskeleton → modify the numbers in the for loops → upload code → repeat.

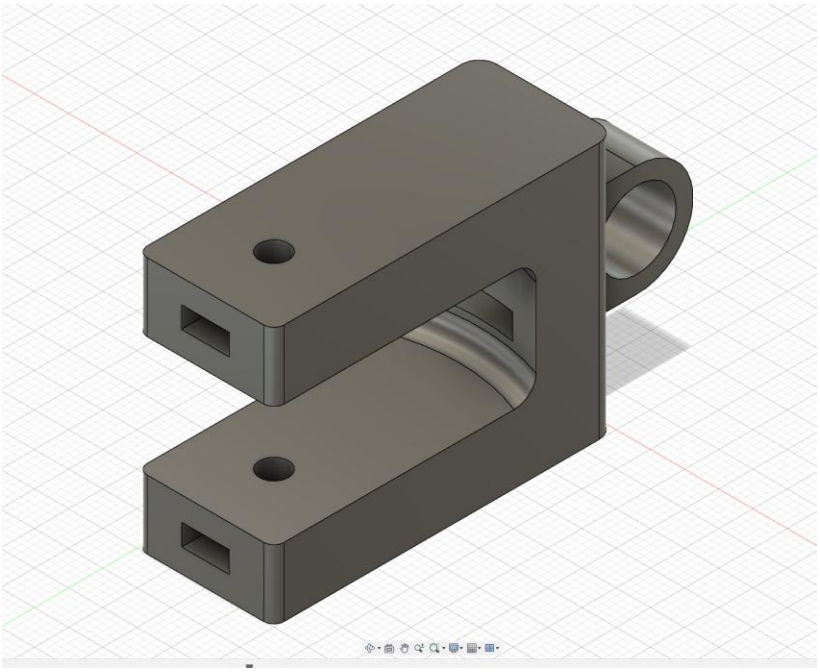
I added pressure sensors at the end of the day and recorded the data shown in the Serial Monitor for each different gait I walked in. I did three trials for each gait. Then I calculated the average of the pressure values for each gait.

2024 Summer Break

Day 15 2024-08-10

I tested springs of different lengths and radii to determine how strong I wanted the springs on my exoskeleton to be. I decided to add springs to the calf section of the exoskeleton because ?. In the end, I chose 2*10*280 springs.

I finished modeling and 3D printing the components that would attach the springs to the exoskeleton



Day 16 2024-08-11

I started by annotating my code from last summer break. For the new version of this exoskeleton, I wanted to just code for the gait of a healthy adult instead of coding based on the exoskeleton user's gait. I mainly did research on the joint angles of a healthy gait today (roughly 5 hours of research). It was more challenging to find data than I expected. Most studies reported gait kinematics on specific groups of individuals such as the elderly or individuals with mobility issues.

I realized that the calf acrylic boards I laser-cut last summer started shattering. I laser-cut them again and switched the old ones with the new ones.

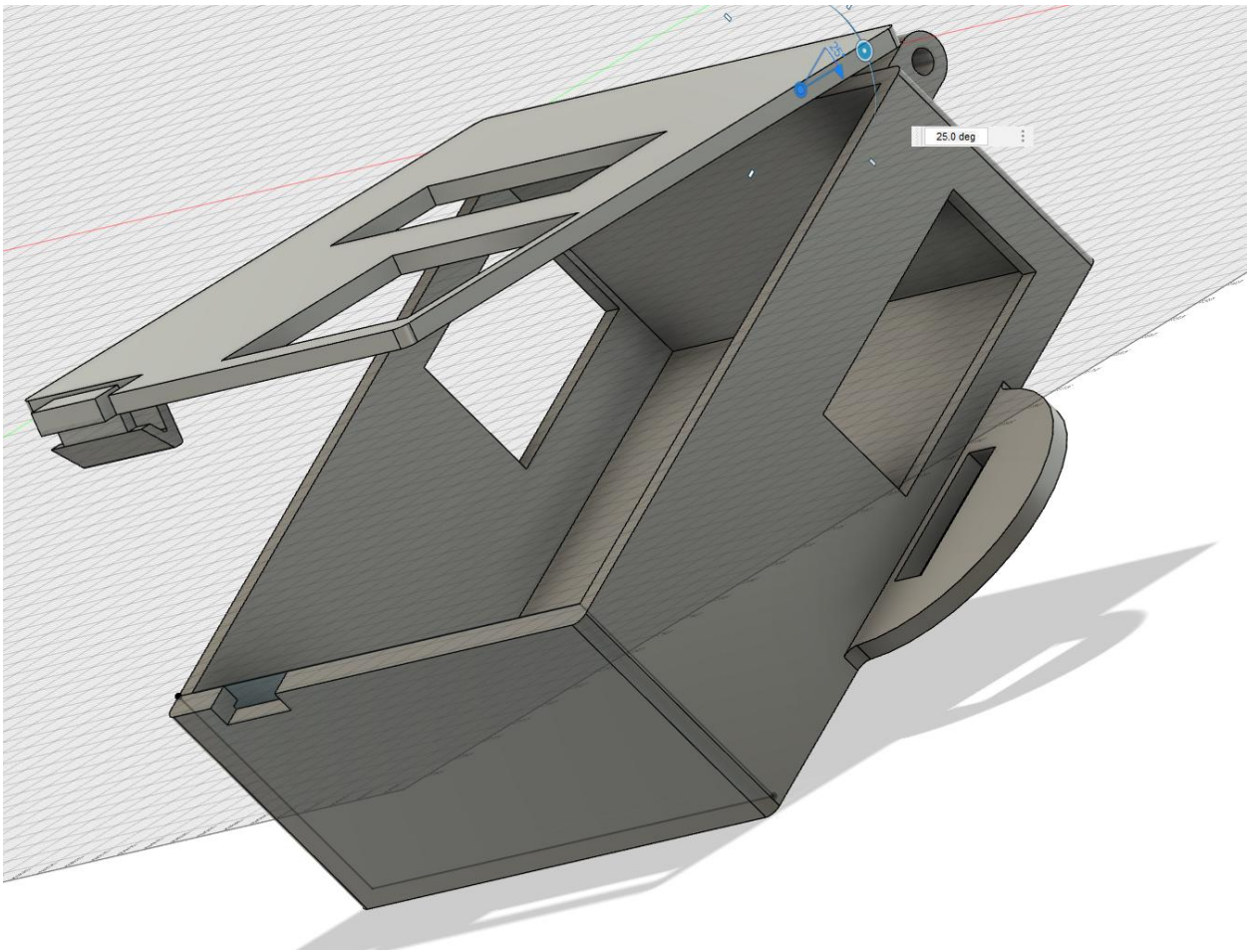
Day 17 2024-08-12

I started the day by identifying the starting angle positions of the four Servos. I did this by marking a specific spot on the Servo wheel with a white sticky tab. Then, I used the Servo code to manipulate the motors so that they turned 30°, 90°, and 180°. This took up most of the day because the values of the starting angle positions somehow kept changing.

To switch things up, I started looking at laser sensors because I wanted the exoskeleton to be able to identify a change in slope.

Day 18 2024-08-13

I designed and 3D printed a box to hold the Arduino Nano control board. Previously, it was zip-tied to the exoskeleton.




The latch that secures the box cover when closed is inspired by the latches you can normally find on TV controllers or other devices with a cover over batteries. Perfecting the latch so that the box would close perfectly took multiple trial-and-errors because there was always a section of the latch that I didn't extrude properly.

I finalized the starting angle positions of the four Servos and added them to a file for constants. My code for the exoskeleton will have to refer back to this constants file.

```
#define hipLOffset 47
#define kneeLOffset 73
#define hipROffset 51 //82
#define kneeROffset 22 //25

#define l1 34
#define l2 26

#define stepClearance 1
#define stepHeight 10
```

Days 19-25 2024-08-(14-20)

Based on the constants I determined, I started calculating and coding how I wanted the Servos to reach the desired angle position for a normal walking gait. This was a very frustrating period because the Servos would not rotate in the way I wanted them to. The screenshot below shows the large amount of calculations and coding annotations I went through.

```
  kneeR.write(22); //22
  hipL.write(47);
  //kneeL.write(80);
  //delay(500);
  for (int i=51; i<=90; i+=5){
    hipR.write (i + 10); // i
   // kneeR.write (i/1.7);
    hipL.write ((0.77)*i+22.23);
    //kneeL.write((i*(1.3))-44);
    //int a = 23+(i-51)*1.25;
    //int b = i-10;
    int a = (1.03)*i-29.53; //(1.03)*i-29.53
    int b = (1.03)*i-12.7;
    kneeR.write (a);
    kneeL.write (b);
    Serial.print(a);
    Serial.print("            ");
    Serial.println(b);
    delay (200);
  }
}


/*
//kneeR.write(22); //104
    for (int i=22; i<73; i+=5) { // Move knee Servos forwards //104, 140
      // kneeR.write (i); // Supposed to move kneeR from 50 to 90 degrees with increments of 5 degrees
      kneeR.write (i); // Supposed to move kneeL from 40 to 80 degrees with increments of 5
      delay (100);
    }

    //hipL.write (90);
    for (int i=47; i>17; i-=5){
      hipL.write (i);
      delay (50);
    }
    //kneeL.write(73); //104
    for (int i=73; i>22; i-=5) { // Move knee Servos forwards //104, 140
      // kneeR.write (i); // Supposed to move kneeR from 50 to 90 degrees with increments of 5 degrees
      kneeL.write (i); // Supposed to move kneeL from 40 to 80 degrees with increments of 5
      delay (100);
    }
*/
```

Day 26 2025-02-13

Accidentally came across a motion tracking software while working on my physics paper for school. I plan on using this software to track a shift in the center of mass.

Day 27 2025-02-25

I worked a bit on my project over winter break before, but only a little every day, so I did not record much in my logbook.

Today marks the first day of testing the exoskeleton on an individual hypotonia. I started today's session with her by recording a video of her walking on flat ground without the exoskeleton as a baseline.

The participant put on the exoskeleton today, but the left knee Servo was rotating correctly, so we concluded the session. I spent the next few days fixing the Servo.

Day 28 2025-02-28

Second session with the testing participant. During today's session, we focused on letting her get familiar with walking with the exoskeleton. I asked her to walk with the exoskeleton on for very short distances while she held on to the kitchen counter for support in case she fell.

Day 29 2025-03-02

Third session with the testing participant. Since she felt more comfortable walking in the exoskeleton, I started filming our session for later use. She walked down the hallway, which had a suitable distance and walls on both sides for support. I would import the video filmed today into the motion tracking software to analyze the shifts in her center of mass. I'd also compare today's video with the baseline video filmed in the first session.

Day 30 2025-03-09

Fourth session with the testing participant. Today I attached force-sensitive resistors on the heel and ball of her feet for pressure analysis. I filmed her walking in the exoskeleton again.

Day 31 2025-03-16

Last session. Same process as session four. I am very happy about how the motion tracking and pressure detection data came out.

# INFORMED CONSENT FORM 2C

CALGARY YOUTH SCIENCE FAIR

You are invited to take part in a research study. Before you decide to be a part of this study, you need to understand the risks and benefits. This consent form provides information about the research. If you agree to participate in this research, you will be asked to sign this consent form before taking part. This process is known as *Informed Consent*.

| Student Researcher (1): Lillian Zhang | Student Researcher (2): |
|---|---|
| School: Western Canada High School | School: |
| School Phone: 403-228-5363 | School Phone: |

Project Title: Lower Limb Auxiliary Exoskeleton with Gait Management Feedback for Hypotonia

Science Fair Coordinator (Adult Supervisor):

Name: Rong Cui Phone: 403-542-9180

Project Description: The Lower Limb Auxiliary Exoskeleton with Gait Management Feedback for Hypotonia focuses on developing a wearable assistive device to enhance mobility for individuals with muscle weakness. The exoskeleton provides structural support and incorporates gait management feedback to monitor muscle engagement (balanced force exertion). A human participant with hypotonia will be testing its efficacy by walking in it, allowing for real-world evaluation of its impact on movement and posture. This research aims to improve mobility solutions and contribute to the development of adaptive assistive technologies.

Your benefits from participating: Benefits of practicing to walk with a better balance, testing a potentially new form of physiotherapy for hypotonia

Your risks from participating: Potential risks of falling and bruising

Your time commitment: 5 sessions, 1 hour per session

The confidentiality of your data:

The results of this research will be given with all information about individual participants removed. No personal information will be stored on a computer. All information on paper that could be used to identify individuals will be shredded at the end of the research project.

Withdrawal:

Your participation is voluntary, and you have the right to withdraw at any time for any reason. If you wish to do so, please talk to the Science Fair Coordinator/Adult Supervisor.

Review:

This project has been reviewed by the Ethics Committee of the Calgary Youth Science Fair Society and has received permission to proceed.

Feedback:

The results of this research will be provided to you in the public presentation of the Science Fair Project.

By signing below, you are agreeing to participate in this study.

Name Emily Jiang (please print)

Signature Emily Jiang Date Feb 25, 2025

***If this participant is under the age of 18, permission of a parent or guardian is also required:***

I give permission for the person named above to participate in this study.

Name Li Xu (please print) Phone 403 305 2324

Signature [signature] Date Feb 25, 2025.