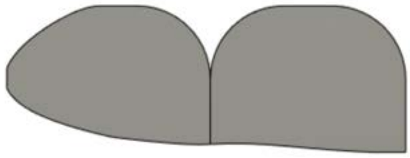
Evidence and Application of Practical Skills

CAD Modelling

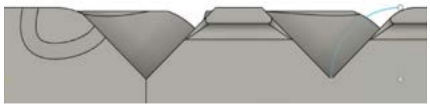
CAD modelling in general on Fusion 360 was an **extremely extensive, complex and the most time consuming process for my design project**. As while modelling, not only do I have to get the desired shape, I have to ensure that the tolerances between gaps are wide enough, ensure that moving parts do not interfere wih one another, create spaces for the fishing line tendons to travel, create enclosures for the electronics and motors, consider the structural strength of each individual piece and still attempt to keep the proportions of the arm moderately accurate. If any one of these is off, then the entire prouct fails. In order to accomplish this with Fusion 360, a parametric modelling program that doesn't allow you to directly drag and move faces, I was able to use a process of creating a basic sketch outline of the shape I wanted, then creating multiple outlines from different angles to essentially cut off excess pieces and 'sculpt' out the piece that I wanted. Using cut and sweep tools. For more organic curved pieces, I used the form workspace and was able to create curved surfaces then attach them onto the other more rectangular models I had modelled
View my accompanying video for brief time lapses on this process.

1.1. CAD: Modelling Fingers

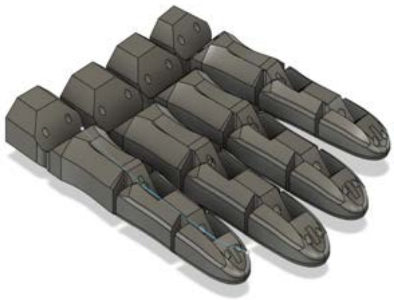
1. I created three separate basic rectangles 24, 25 and 28 mm long and 15mm wide. representing the three segments of the fingers then cut out a 45 degree triangle from the midpoint of the touching faces on the rectangles, creating the area where the fingers would bend.



2. From this I was able to then add another rectangular layer beside the original and cut out a circle to finish the slots where the fingers fit together.



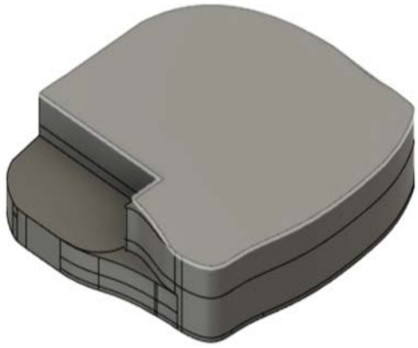
3. Using the pipe tool, I then cut out continuous 2mm holes through the centre of the fingers where the fishing lines would fit through, with the hole at the base finger segment diverging into two separate holes



4. I then sculpted the outline of the fingers with curves and used the fillet tool to curve the corners of the rectangles, being careful that these changes do not interfere too much with the existing structures. This stage included a lot of trial and error to get an aesthetic model that resembled fingers.

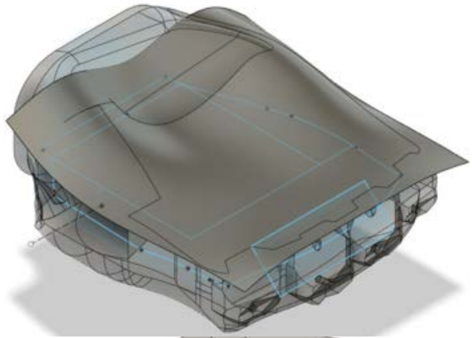
Ongoing Evaluation:
At this point, the modelling of the fingers took over a week of solid work in my holiday time, which was much longer than I had expected and wanted it to. This delayed the rest of my project's progress, as the rest of the design, including the positioning and orientation of the motor will depend on how the fingers function. Overall the modelling of these fingers really wore me out as there was an immense amount of trial and error, andj me trying to logically piece together each of the 20 parts while still keeping in mind it has to attach itself to a hand. This lead me to many late nights in the holidays.

1.2. CAD: Palm Modelling



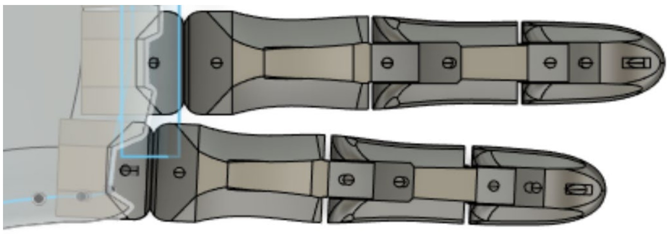
1. Using a picture of my own hand as reference, I created a basic outline of my palm and extruded to the approximate maximum thickness of my own palm at 40mm.

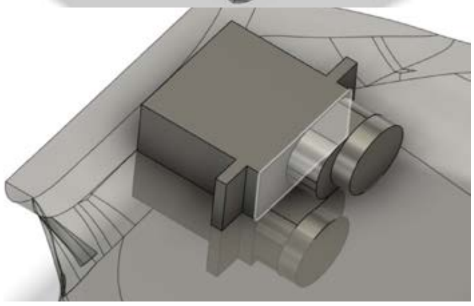
2. I then used the form tool to create an organic palm surface and back that closely resembled the contours of the palm, then used the replace face tool to get the original block to adhere to these contours.



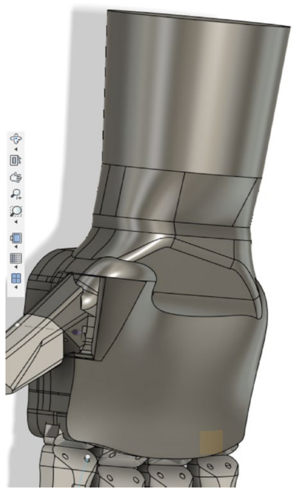
3. I then combined the existing base of the fingers with the tip outline of the top of the palm to combine the designs

4. After this I then created approximations of the motors I would slot in, positioned them in the general position I thought they would be in as seen to the right, then cut out the slots for the fishing lines to go through leading to the motors. Ensuring that there was at least a minimum of 20mm of free material on each side of the motors.





1.3. CAD: Wrist

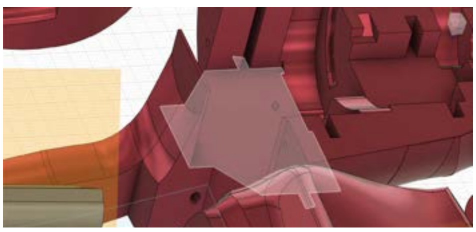


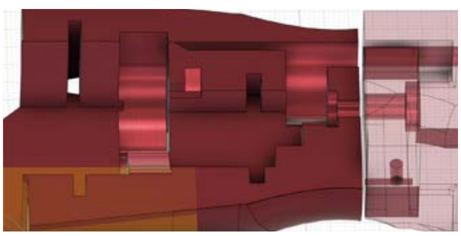
1. From the palm I extruded a cylinder with diameter 60 mm that widened by an angle of 5 degrees 160mm long.

2. I then placed the motor models I made in step 1.2 into the arm, realising that some areas were too thin, I then increased the diameter of the centre segment of the wrist by 4mm to compensate.

3. I then coloured the arm red (as I was sick of seeing grey) and split the body in two, allowing me to create the slots for the motors to fit in, as well as allowing for the parts and all the interior moving pieces to be accessed for assembly later on.

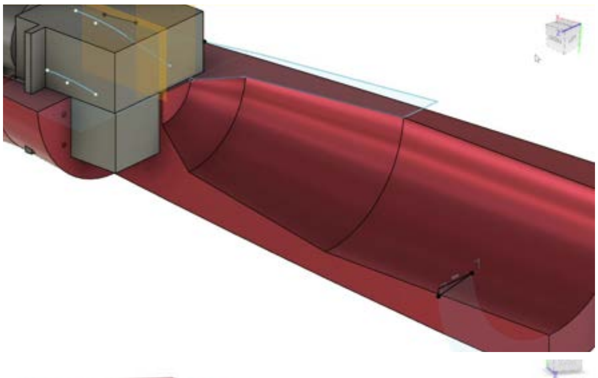
4. I extruded a space for a small servo in the wrist, then for two larger servos at the rear of the wristQ, ensuring they have a sufficient gap to account for 3D printer error.

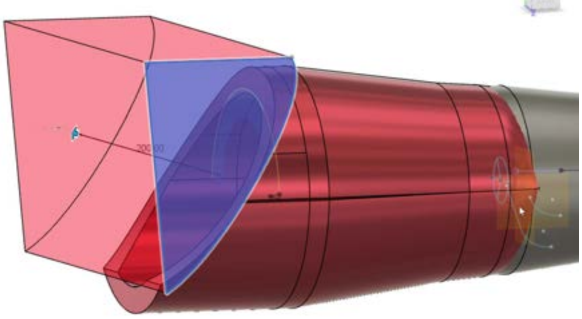


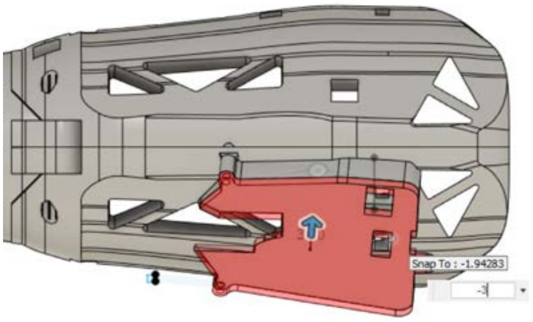


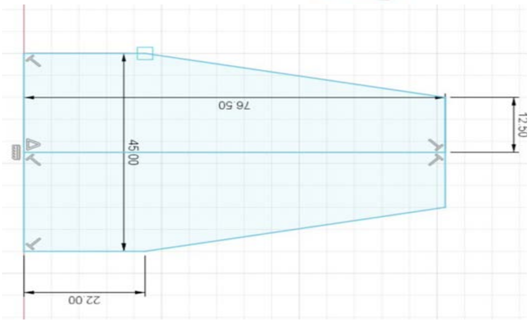
1.4. Socket and Electronic Casings

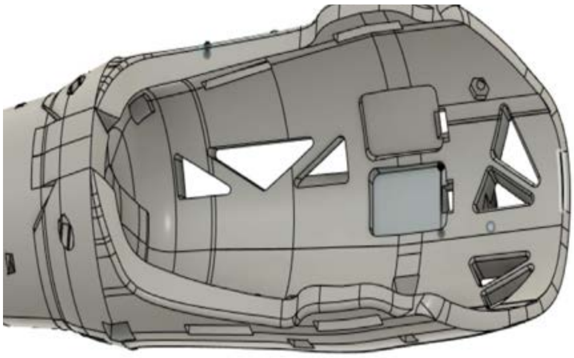
1. For the Socket i traced the contours of my arm on Fusion 360
2. I then used the revolve tool to create a circular form around it, ensuring that the minimum thickness of any area was 6mm
3. I then removed the upper half, and created triangular holes for breathability and the slots for the sensors, velcro and wiring to fit through.
4. I then modelled in the screw holes and slots for the wiring, cases and electronics to fit into, as well as the connection to the wrist.



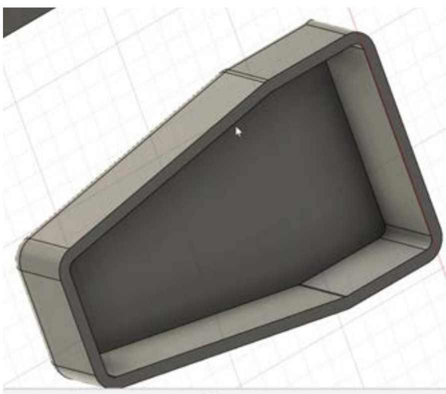


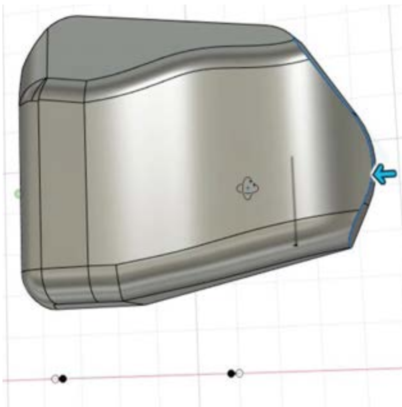


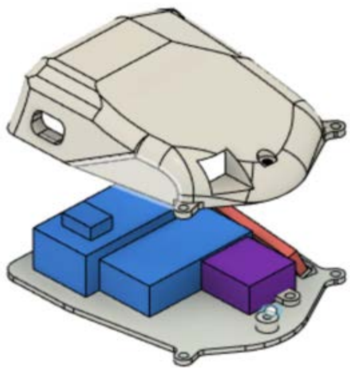




1. For the Electronics casings I did a quick outline of the minimum boundaries required to contain the electronics.
2. I then used the offset tool to create an additional 3mm perimeter around the area
3. I then extruded this and created a roof over the top of it
4. Using this, I then cut out and filleted the model, giving it rounded surfaces and a more organic appearance
5. I then added the screwholes and places for the wiring inside to exit from.

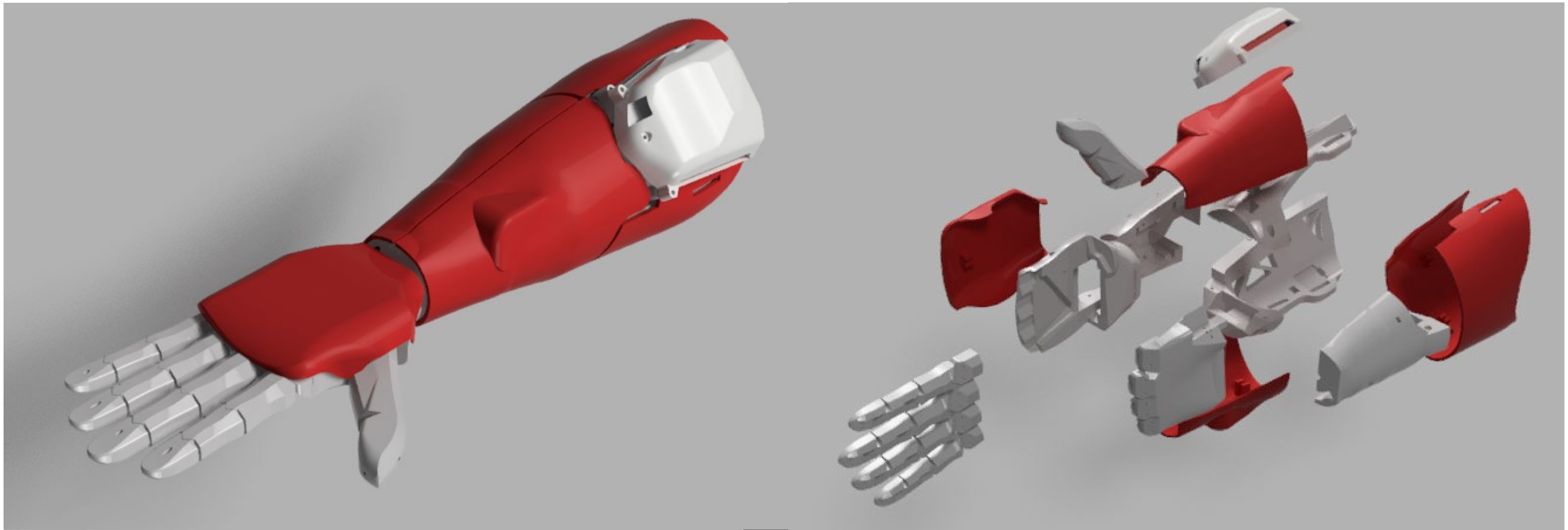


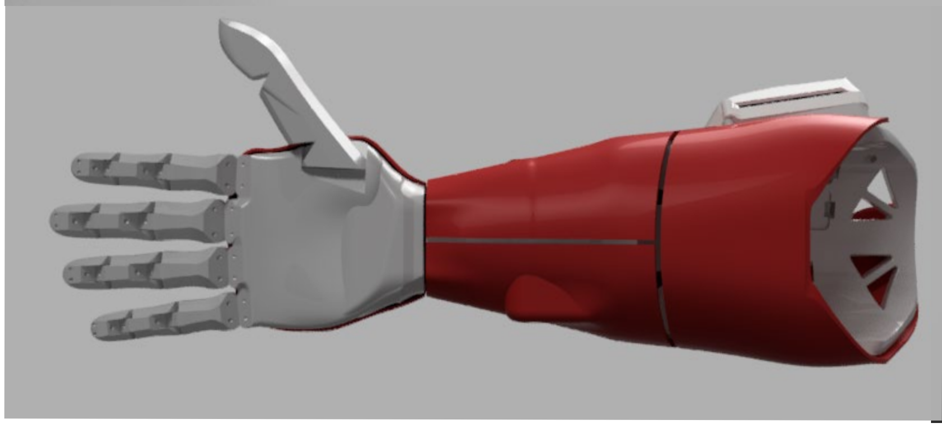


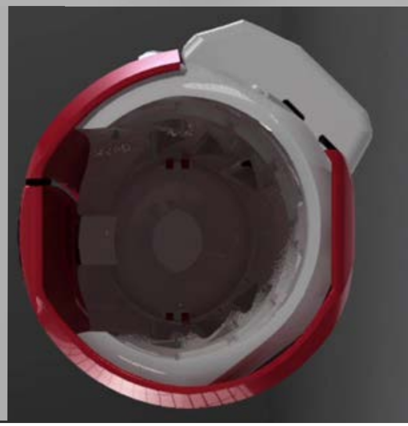


Final Render

This is the final rendered model created in Fusion 360 with the colour scheme that I intend to have. I have tried to match it as close to possible as the original final sketch however after research, experimentation, and the process of actually modelling the design there are a few minor adjustments. A main difference was the lack of lights on the hand part itself, the use of velcrp instead of string, and minor structural and cosmetic adjustments. Unfortunately I couldn't find room to place the vibration motor for haptic feedback in.







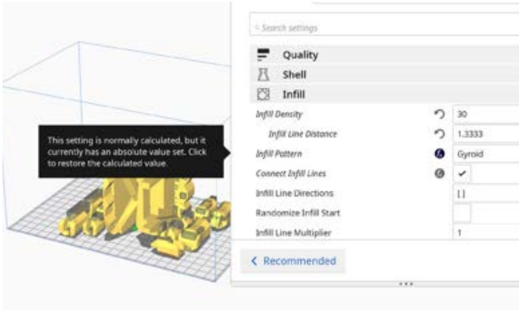
I stuck with a relatively minimalistic case to show case a 'blank canvas' type of effect to show that the design can be customised. **I later added a separate armband to house the battery pack not seen here**

Ongoing Evaluation

I had a massive sense of relief as I was doing these images as it meant that my project was actually coming together. Especially due to COVID constantly messing things up, it was nice seeing something actually work.

2. 3D printing

Theoretically, after 3D printing, I should have been able to just set the correct settings in the slicer software **(see page 53)**, then print. However inbetween each print I had to level the build plate, clean the nozzle and check on the filament. Additionally, for each print I had to watch the first layer to ensure that it stuck to the plate.

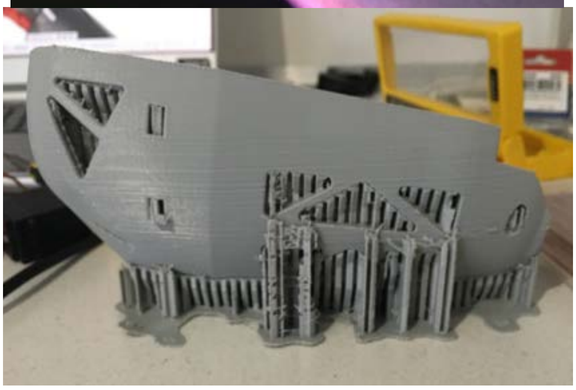


1. I imported my final files to cura slicing software using the following infill settings to get the required strength. In order to maximise the strength of the part, all my pieces were printed layed out horizontally with the following settings
Infill: 30%, Layer height: 0.2 mm, Print temp: 205 C
Infill pattern: Gyroid, Wall thickness: 1.2 mm, Print speed: 45mm/s, Raft enabled.

Top Wrist Piece approx. 7hrs

For the fingers and palm prints, I had to create support blockers for all of the smaller holes and structures in the model, to prevent structures from being built in there, as these are almost impossible to remove.

2. Using the utilities option on the makerbot printer, I manually adjusted and levelled the build plate, sliding a piece of paper underneath the nozzle at varying point sof the plate. Tightening and loosening the plate springs as needed.

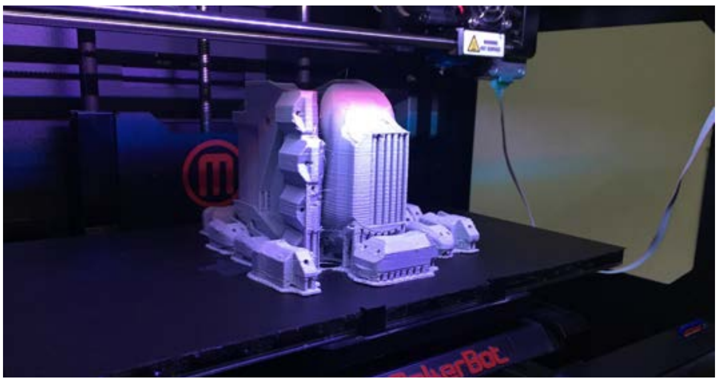


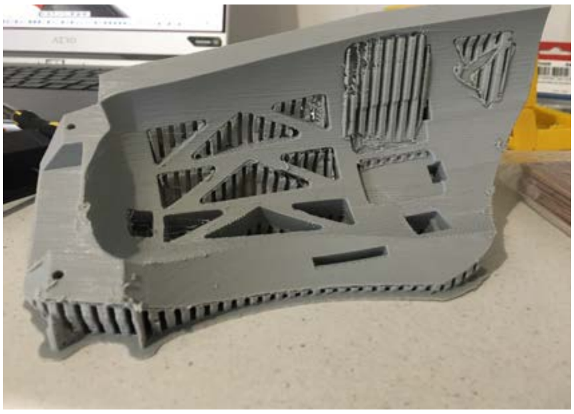
3. I then printed out each of the pieces. Ensuring that I was on standby to monitor the filament and print itself. Especially checking for proper bed adhesion in the first few layers of the print.

4. While each of the prints were printing, I was removing the support and raft structures from each of the print. This was a little difficult for the smaller triangles and holes you see to the right.

Right and Left Socket approx. 26 hrs

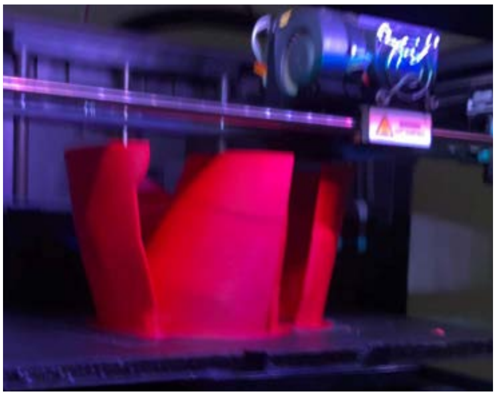
Hand and fingers approx. 15 hrs



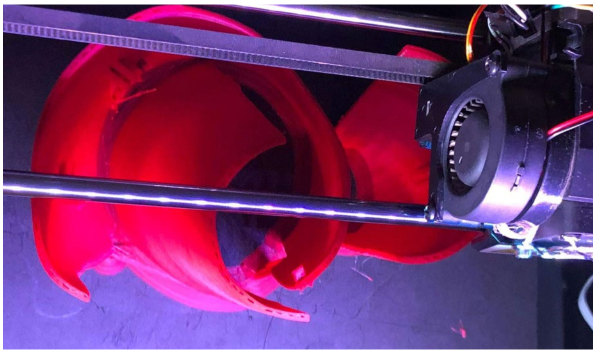


For the smaller support holes, I was able to use a combination of pliers, a stanley knife and scissors to scrape off the remainder of the support materials which stubbornly remained on the surface of the prints.

5. I employed slightly different print settings when printing out the outer cases of the hand, prioritising appearance more than strength to minimise the post processing needed and increase final surface quality. I altered Layer height: 0.2 -> 0.15mm and due to how thin the parts were, increased print speed from 45mm/s to 60mm/s



Actual print times for all of the pieces varied, however I was able to group up large assemblies of small components to reduce the amount of time wasted between each print. the largest component, the two forearm pieces took 26 hours to print while the other groups took on average 5-10 hours per print. Leading to a total print time of over 100+ hours for this project alone. Even moreso when counting the failures or “learning opportunities”



Ongoing Evaluation:

The sheer amount of manual adjustments and the finicky nature of 3D printing machinery drove me mad here, as I despite my preparation for this process, there were many parts that failed and lead me to hours of trouble shooting only for the next print to work with seemingly no changes, and vice versa, where everything seems calibrated and suddenly everything goes wrong and it stops midway through your next 20hr long print. I was however able to persist and get everything to print at a reasonable quality.

3.Post Processing

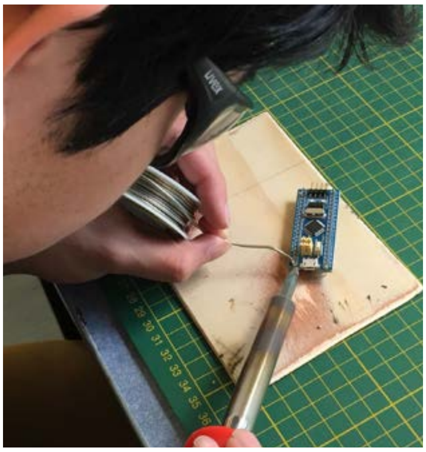
As the machines I used, and my experience in 3D printing settings and optimisation are limited, as well as due to the general limitations of Fused Deposition Modelling (FDM) quality, my printed models require extensive post processing to reach an acceptable surface quality.

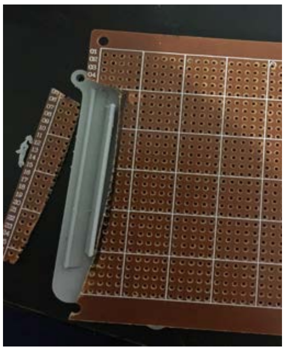
Partial Assembly of parts

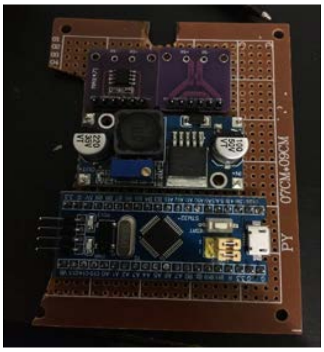
1. After the prints are removed from the build plate, briefly sand down any visible excess material present on surfaces, including from stringing, rafts, or support materials with a 120 grit sand paper. Removing any large removing support structures with a small file.
2. To ensure parts work, I briefly assembled the components together to see how they would appear and whether they all held together. slotting the m3 screws into their corresponding holes.
3. I then sanded the entirety of the 3D printed surfaces with a 240 grit sandpaper, pressing down only lightly and in circular motions to roughen up and prepare the surfaces for spray painting
4. Once I knew they worked I dissassembled and removed the plastic pieces and placed the larger parts on a plastic sheet and strung the fingers up and hung them on a bar.
5. I then sprayed each of the surfaces and let dry between each one. Because of the cold weather this process took overnight for the parts to dry sufficiently enough for sanding
6. Once dry I lightly sanded the surfaces to further smoothen them, then sprayed another layer of paint over the top. Repeating twice and allowing sufficient drying between each coat.

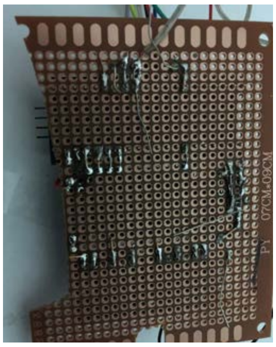
4. Soldering

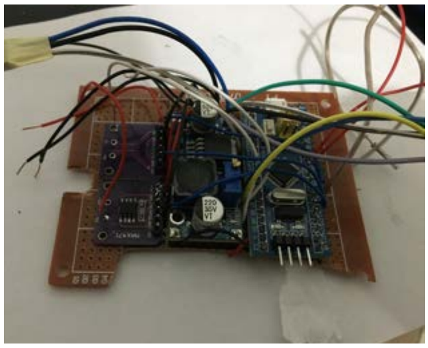
1. I soldered all the headers which accompanied each of the boards into their respective areas.
2.Using my 3D print as reference, I cut out a segment of a perfboard to accomodate for the LED strip holder which is integrated into the base plate.
3. I then arranged the electronics onto the platein order to check if they fit and make any final minor adjustments
4. I then soldered everything in place, and joined non adjacent connections via solidcore jumper wires
5. I then soldered jumper cables which will connect to the motors, with precrimped ends to their respective positions as according to the schematic in the following page.





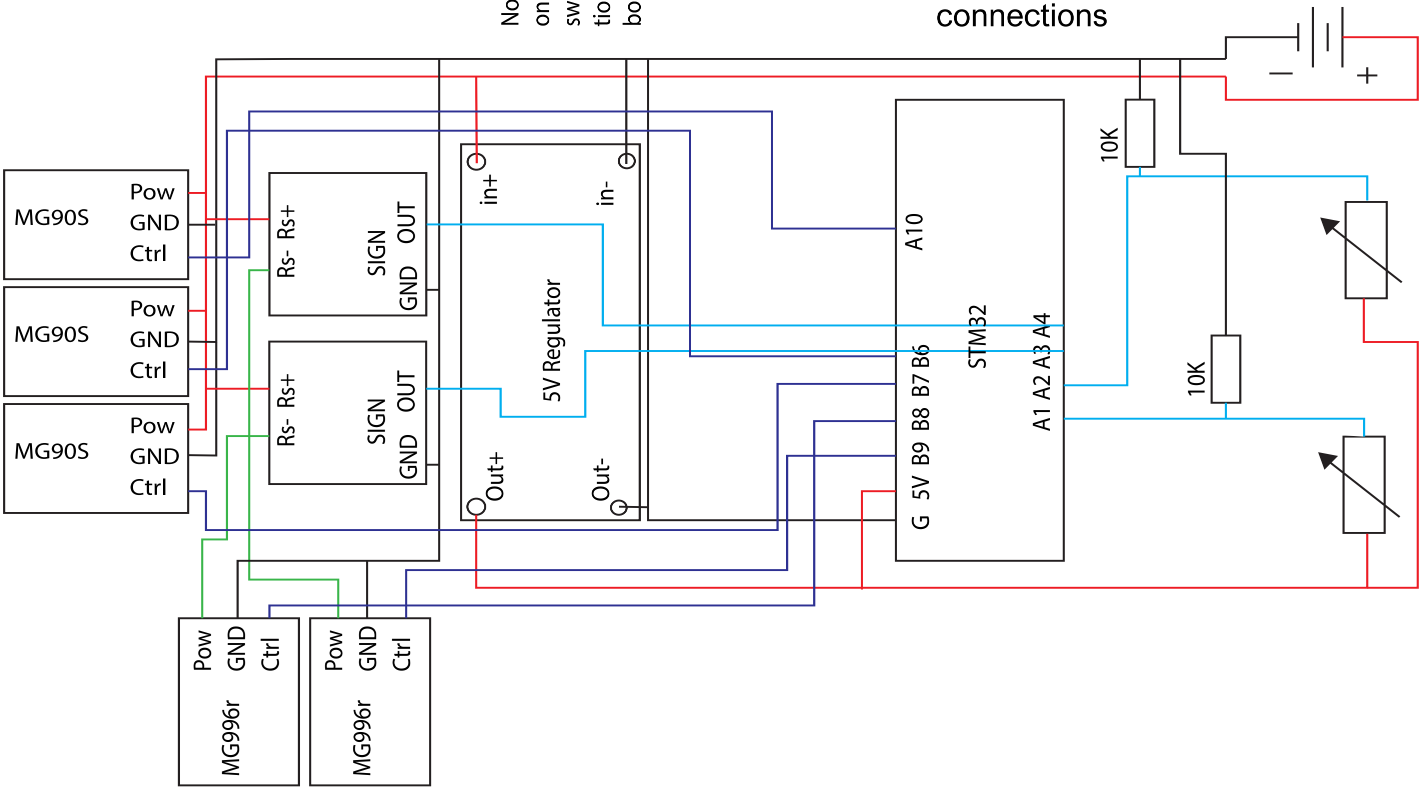






Note, in and out on regulators swapped position on actual board

Schematic Diagram I created to use as reference when soldering connections



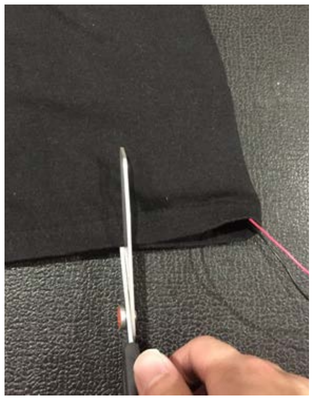
Ongoing Evaluation

In hindsight I probably should have tested this circuit on a breadboard before soldering, as I had wired each circuit individually but not all together like this before. Luckily it did end up working. This part was extremely stressful for me as I extremely dislike the process of soldering and am still new at it. I was originally planning just to use a temporary breadboard however I resorted to soldering as it was the only way to get the electronics compact enough to fit in the enclosure. Originally I had thought this would only take one or two hours, however it took me a span of two days to be able to organise and solder everything together due to my limited skill level.

Sewing Straps and Battery holder Pack

Originally I had attempted to sew up these components myself, however I found mself unable to securely and neatly sew the components I needed together as seen in the images of my attempts below. I had already cut up the pieces I needed, so I asked my dad to sew the pieces together for me, as he had more experience with sewing.

My failed attempts at sewing, resulting in the string coming undone and creating a tangle of line.



Cutting shape for battery holder

End product battery holder with the attached velcro strap and snap connectors. (thanks dad)

Coding

The coding of this design for me was a frustrating step given I am still a relative novice at it. For this, it was mostly a process of trial and error and logical thinking -to try and get the program to understand what you want it to do, as well as trying to remember the proper syntax, capitalisations and grammar to use. My process was to call for sensor reading in the main loop, then create separate functions to control the movements of each motor available, in response to the sensor values.

Small excerpts of the code I have written

```
void setup() {
  // put your setup code her
  pinMode(Wsense, INPUT);
  pinMode(Fsense, INPUT);
  pinMode(Cind, INPUT);
  pinMode(Cpin, INPUT);
  pinMode(ThumbR, OUTPUT);
  pinMode(ThumbC, OUTPUT);
  pinMode(Wrist, OUTPUT);
  pinMode(Index, OUTPUT);
  pinMode(Pinky, OUTPUT);
  pinMode(Pow, OUTPUT);
  pinMode(PB0, INPUT);
```

Preparing sensor and motor pins

```
void loop() {
  // put your main code here, to run
  digitalWrite(Pow, HIGH);
  Wrist_val = analogRead(Wsense); //v
  Fore_val = analogRead(Fsense);
```

Reading and writing sensor data

```
Wval = map(Wrist_val, 2, 1000, 5, 100);
if (Wrist_val > 800) {
Ival = map(Fore_val, 2, 900, 5, 110);
Pval = 5;
```

Convert sensor data to motor angle