Grip Assistive Glove

24-370: Design 1
Department of Mechanical Engineering
Carnegie Mellon University

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Team 2

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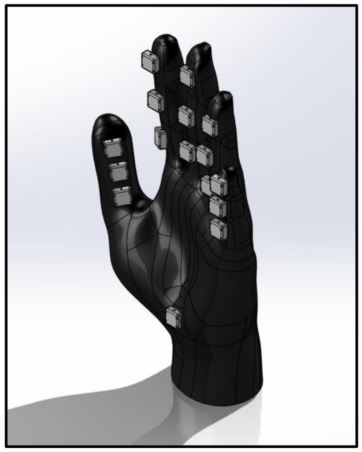
Summary

a.



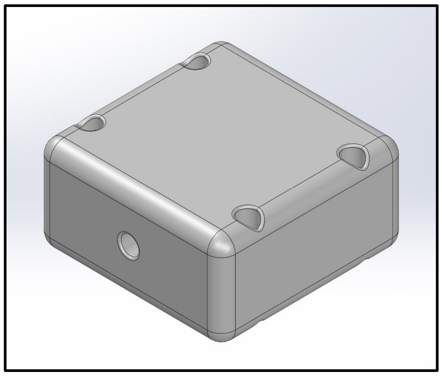
b.

We chose to modify a standard leather glove by creating a mechanism that will assist the user of this product to grip any object and increase their overall grip strength. We found that this particular product would fill a hole in the market as we found that there is a potentially high demand for this product from our user survey results. Since our target population is people that suffer from Cerebral Palsy or Tendonitis, the original product of a leather glove does not provide any assistance in gripping objects, as it doesn't provide any external forces on the user's hands. We decided that we could modify a glove with not too much cost of production and technology on it to produce our product, and we did this because the user survey results were quite positive on this potential product.

c.

The product functionality that seemed to be most important to our target population was the ability to increase grip strength when using this product. This is because there are not many products that offer this functionality and if they did, it would be very difficult for the user to afford and obtain it. We believe that we can make this product affordable to our target population, and we believe that this is another specification that users would find important. We used a motor that pulls on fishing lines that are attached to each finger, this increases the grip strength.

d.



e.
Everyday people that suffer from conditions such as Cerebral Palsy and Tendonitis struggle with completing activities that require grip strength that these people do not have. This product will allow users to wear a glove that will help them grip any object by simply pressing a button.

f.
When users are ready to grip their desired object, they would press a button that activates a motor that pull on fishing lines that are attached to nodes on the fingers. These nodes are attached using adhesives and the motor pulling these lines create the force to mimic gripping.

g.
The sales price of this product would be $46.30.

Early Ideation

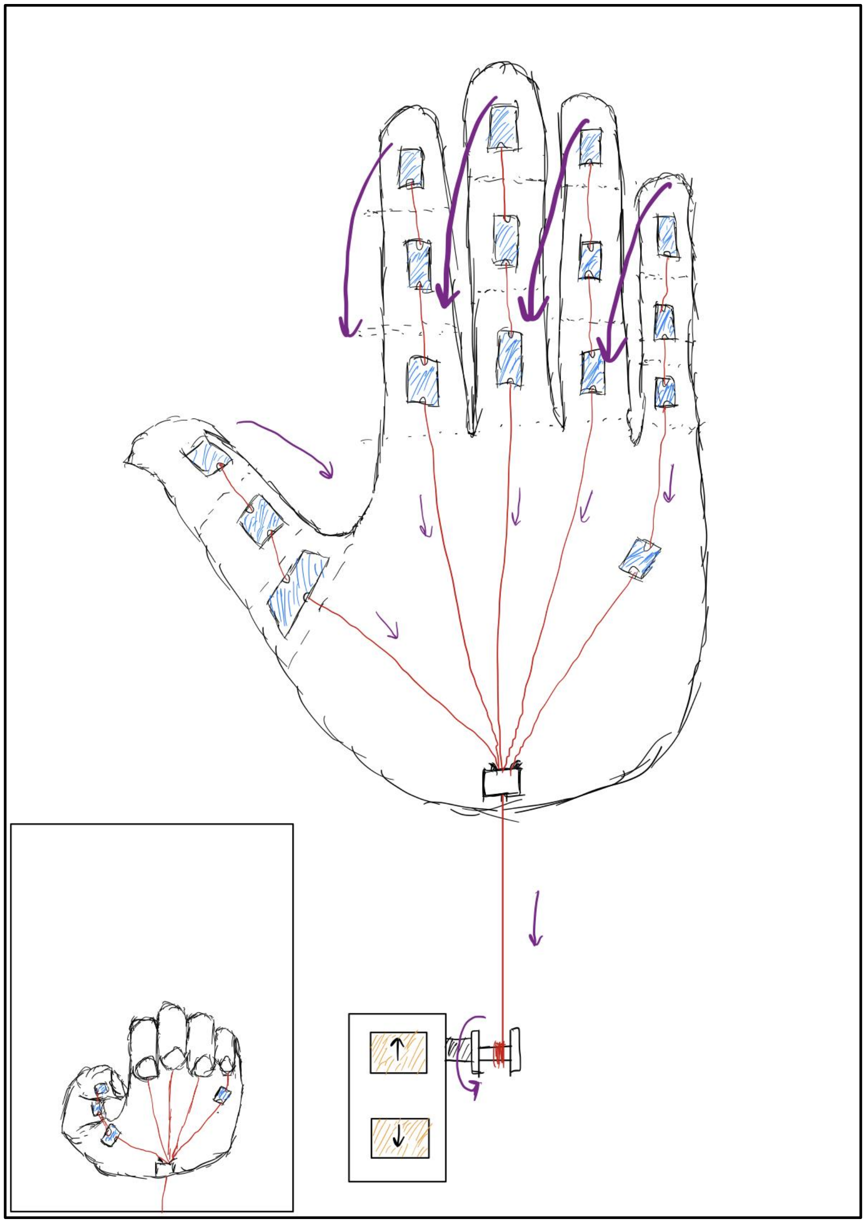


Figure 1: Initial Idea 1

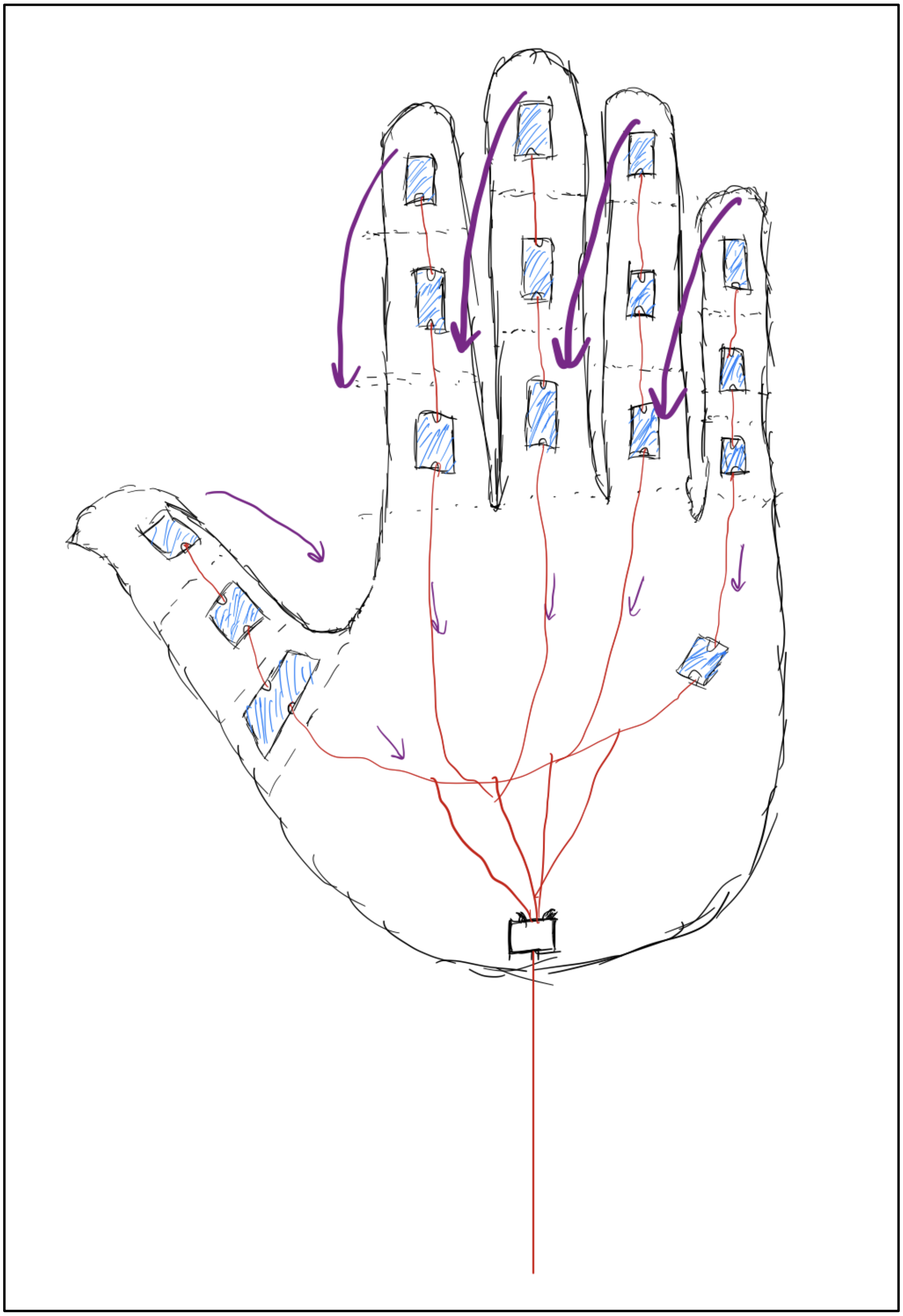


Figure 2: Initial Idea 2

Our first initial sketch contained rings around each joint of the hand, as depicted above. Specifically, the rings will be placed at the center of the distal, intermediate, and proximal phalanges of the hand to ensure that there is maximum tension on the hand to ensure a grip-type form will be created by the hand. We would have fishing wire running through these rings down to the palm of the hand where they would be combined into one string that will interface with the motor. The second design has a different configuration where we connect the strings in sections to try to improve functionality of the grip. From these sketches, we decided to change the one motor setup to a two motor setup to try to increase the overall functionality of the gripper, similar to the second idea sketch. This would make it easier to grip odd shaped objects than before. Furthermore, we decided to include some elastic materials on the back of the glove in order to make it easier for people to open their hands once they decided to release their hand. This would look similar to the current fishing line setup, except with elastic material embedded in the glove.

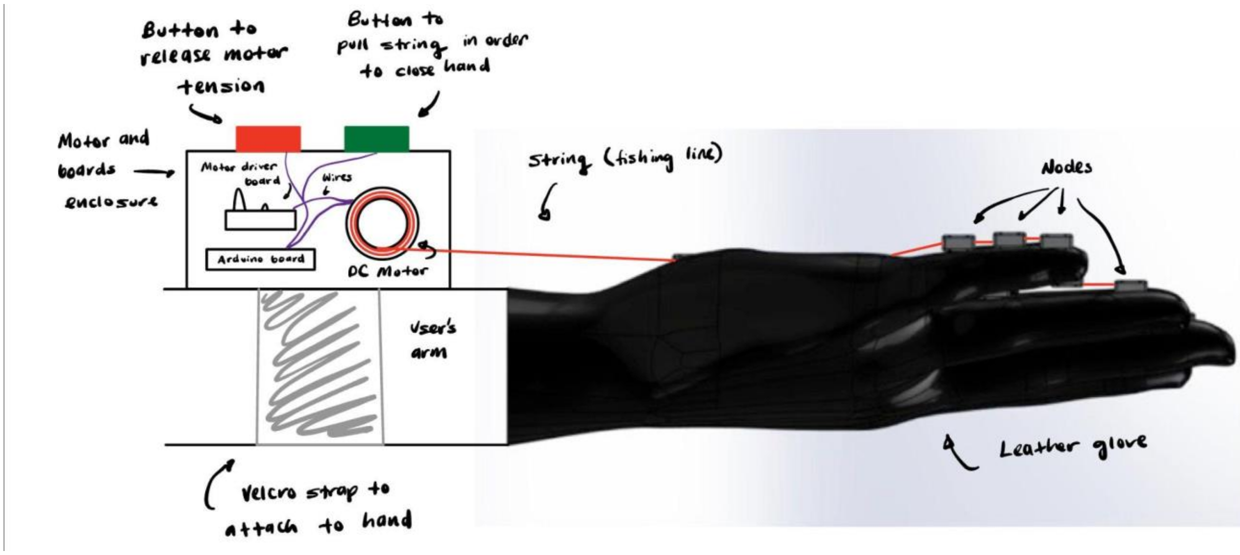
The three most important insights was the fact that we would need a system in place to help open the hands once the gripper was turned off. Furthermore, we would need to be able to maintain the tension in the hand via the fishing line for prolonged use of the gripper. Finally, we need another system in place that would ensure that the string would be wound up when the gripper was released.

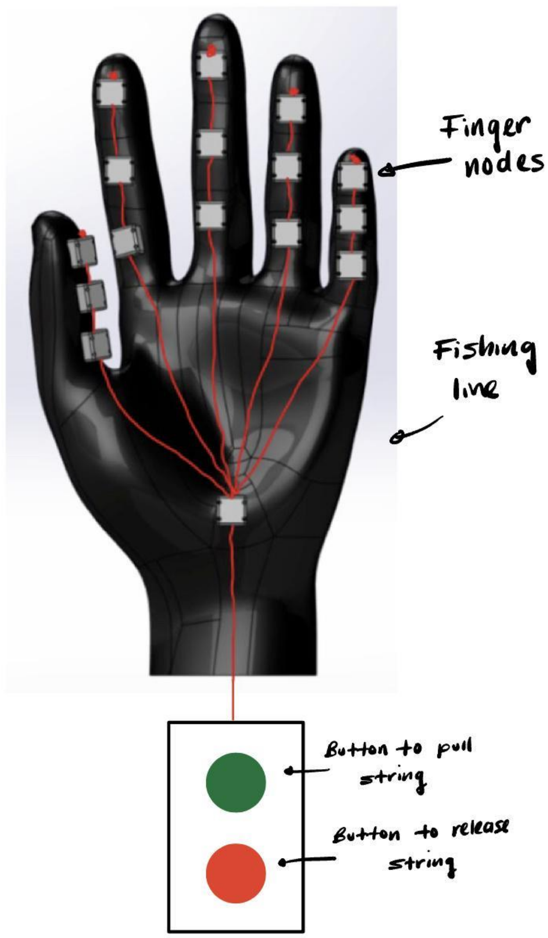
a. Include your two most impactful early ideation sketches. In 200 words or less, describe how they bridged the original product to your final one. Which features were kept? Which were modified or removed, and why. (Include additional tables, calculations, sketches, or any additional supporting material that can support your explanation)
b. What were the 3 most important insights gained from early ideation, sketches, and prototypes?

Developed Ideation

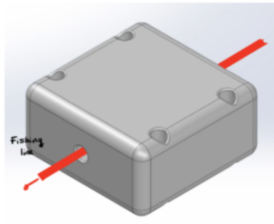
On early ideation we explored the benefits and consequences of using one or two motors to pull the string and close the hand. Initially we planned to do two separate motors but now we are pursuing only using one motor. Through tests and iterations, we lightly tested the difference of pulling all the fingers with one string and then the thumb separately and found them to be very similar. We believe that adding an additional motor is not worth the benefit for the following reason. An extra motor adds weight to the design and makes the enclosure where the motors rest bigger and less discrete. Two motors also changes how the user interacts with the product, as we would need four buttons instead of two, this makes the design more complex and harder to use. Therefore, we ultimately chose to only use one motor for the final design.

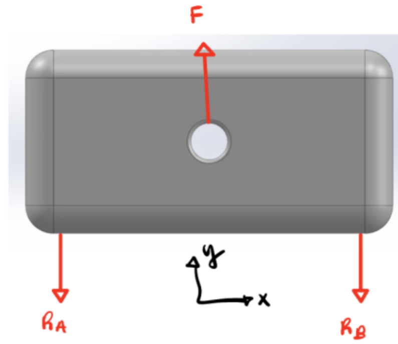
Additionally, we initially planned to have some elastic material on the back of the glove to help the person open their hands once they decide to unwind the string to release their hand. Through iterations, we decided to not pursue this idea since it restricts the hand to be fully open whenever the motor is not engaged to pull the string. Similar effects can be achieved through the user pulling their hand open with their other arm to help unwind the string. Our audience should be able to have normal finger movement even while wearing the glove, and an elastic would be detrimental to this and make the manufacturing process harder and more expensive.





Stress Analysis





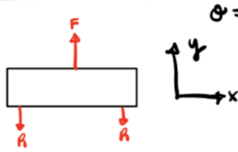
$$\Sigma F_x = 0$$

$$\Sigma F_y = F - R_A - R_B = 0 \qquad \underline{\text{note}}: \; R_A = R_B$$

$$\Rightarrow \quad R_A = \frac{F}{2} \text{ and } R_B = \frac{F}{2}$$

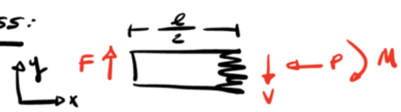
Axial stress:

$$\sigma = \frac{F}{A} = \frac{F}{\ell \cdot w} = \frac{25}{0.001 \cdot 0.001}$$



$\sigma = 25 \text{ MPa}$ (Axial stress)

Shear stress:



$$V = F \qquad P = 0 \qquad M = F \cdot \frac{\ell}{2}$$

$$\tau = \frac{F}{A} = \frac{F}{w \cdot h} = \frac{25}{0.001 \cdot \frac{0.001}{2}} = 50 \text{ MPa}$$

$\tau = 50 \text{ MPa}$ (shear stress)

$$\sigma_b = \frac{My}{I} = \frac{F \cdot \frac{\ell}{2} \cdot \frac{\ell}{2}}{\frac{1}{12} b^3 h} = \frac{25 \cdot \frac{0.001}{2} \cdot \frac{0.001}{2}}{\frac{1}{12}\left(\frac{0.001}{2}\right) \cdot 0.001^3} = 150 \text{ MPa}$$

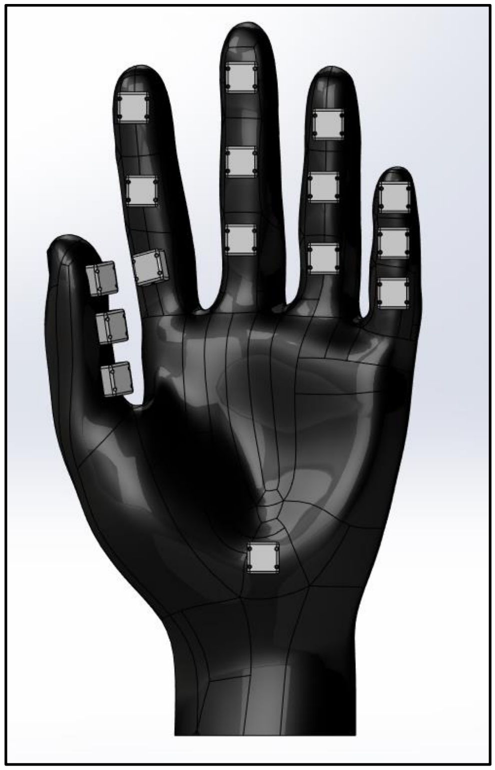
$\sigma_b = 150 \text{ MPa}$ (bending stress)

Assumptions: The stall torque of the motor equals 25 Nm, therefore we assume the force applied on the nodes equals this for the state we are studying. The nodes are attached to the fingers by glue and fishing line which creates two reaction forces that oppose the force applied by the string running through the middle of the nodes. The fishing line we use is rated for 40 pounds, which is sufficient to support tension applied by the motor, no calculations are necessary.

Prototype in CAD

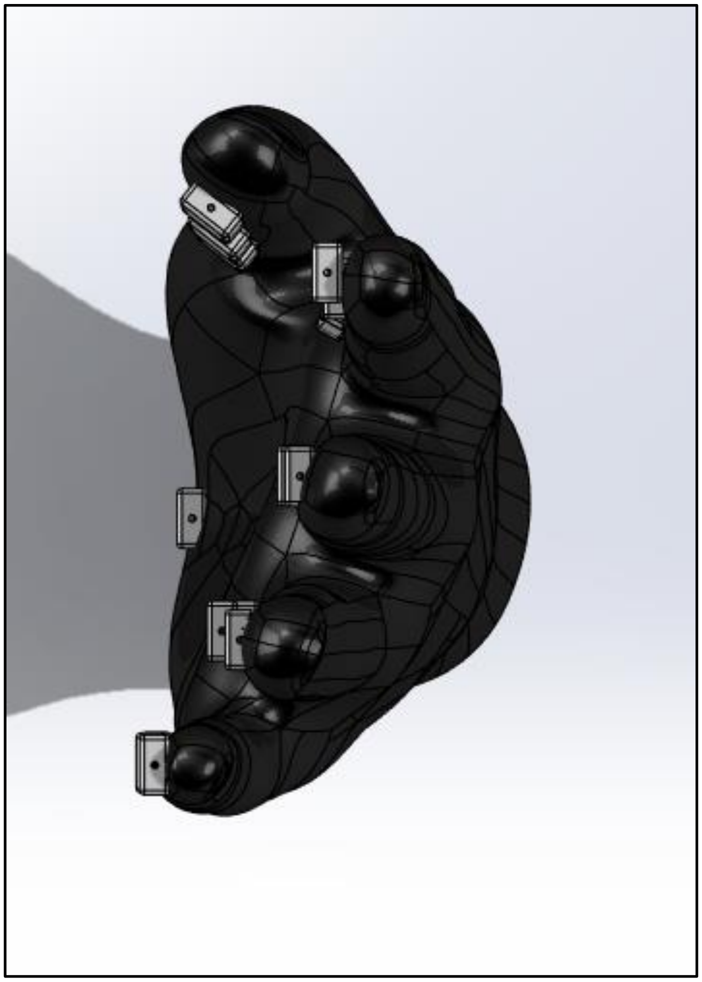
a.) Product Assembly:

Front View

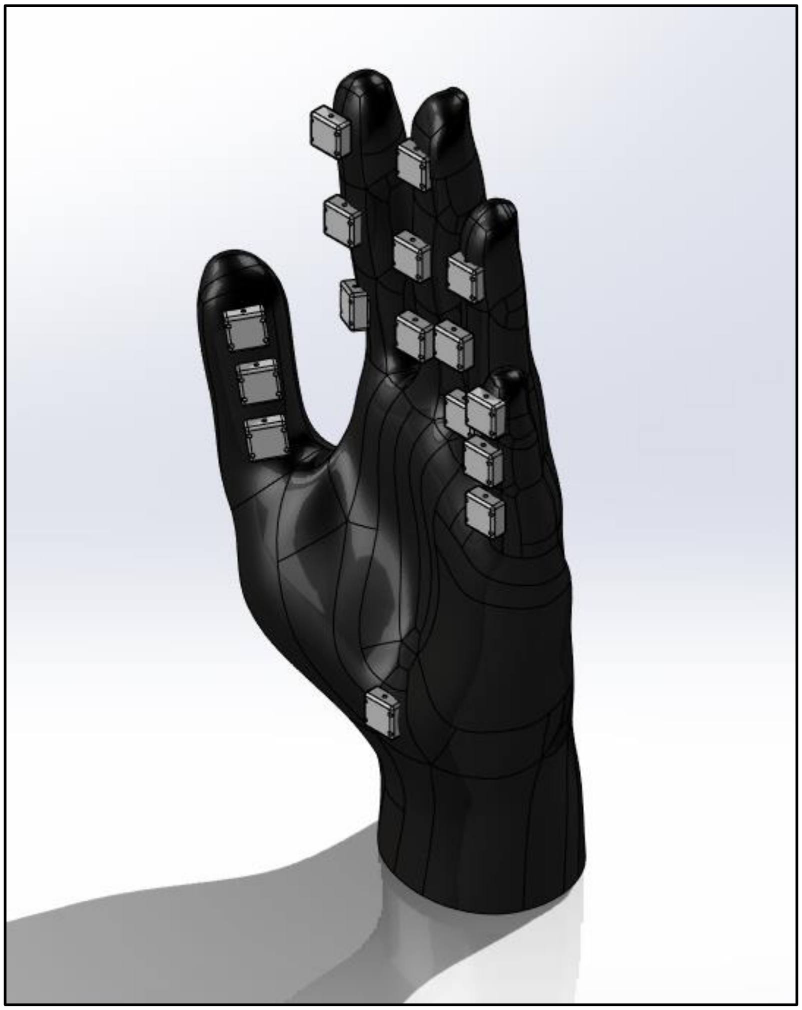


Right View

Top View

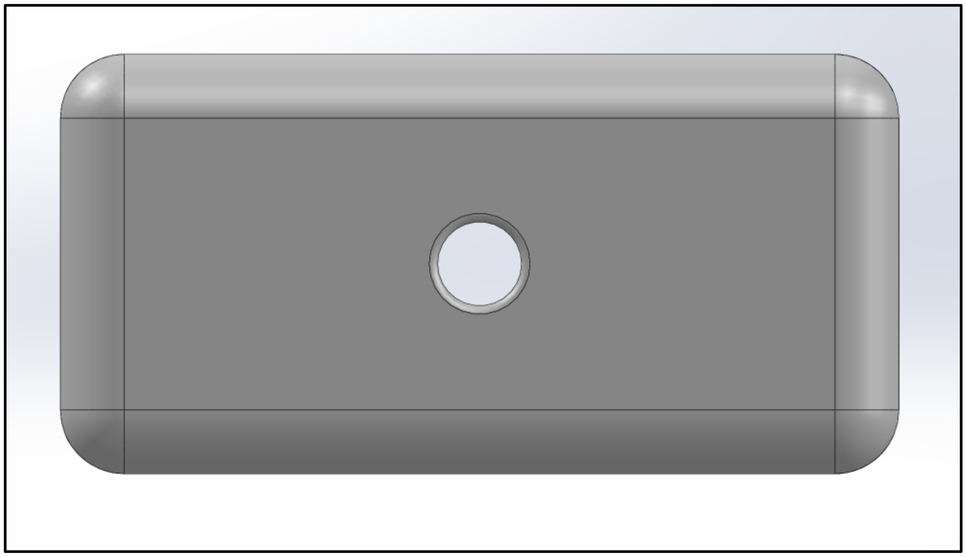


Isometric View

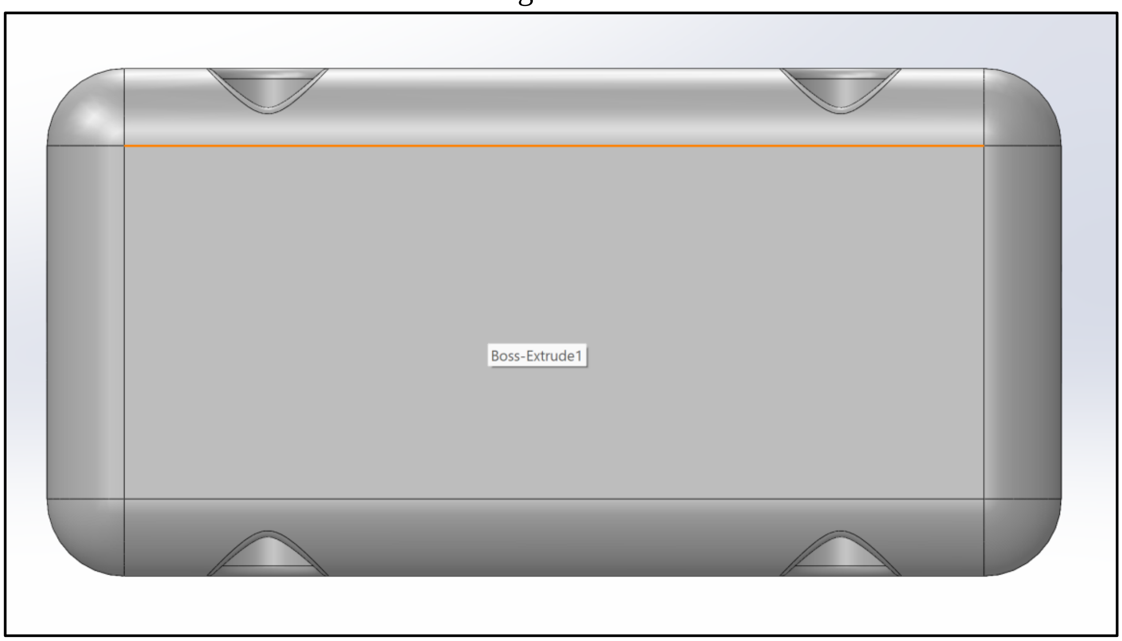


b.) Node Subassembly:

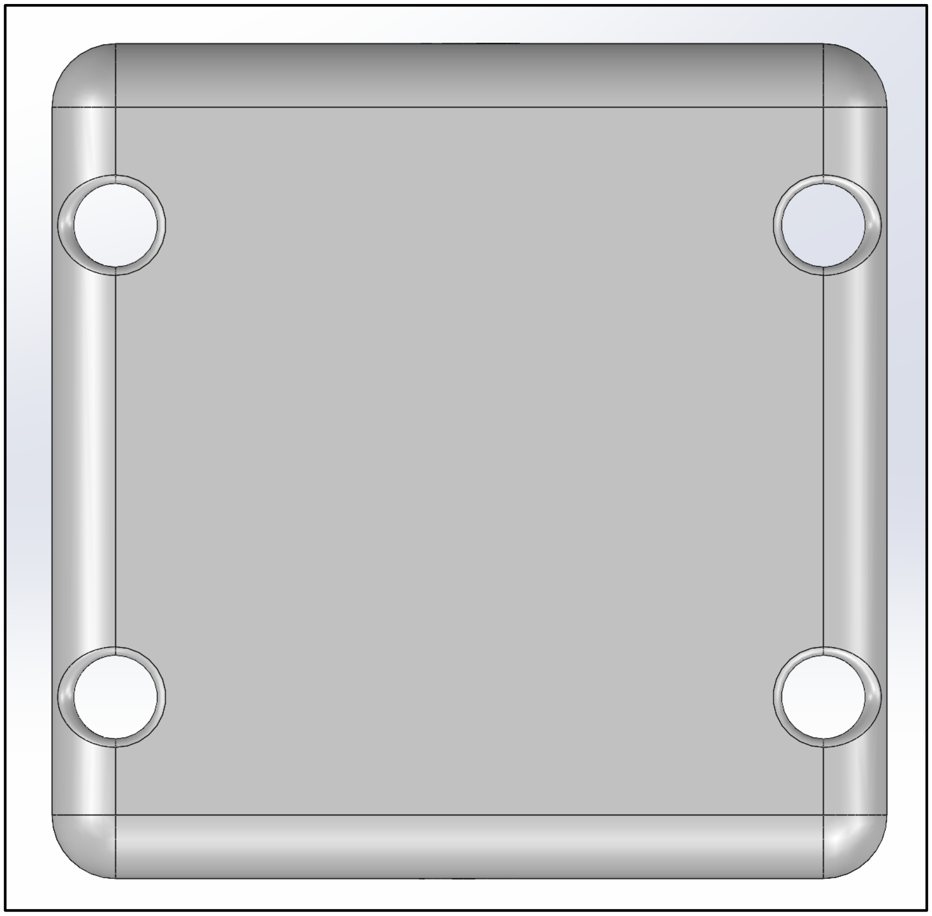
Front View



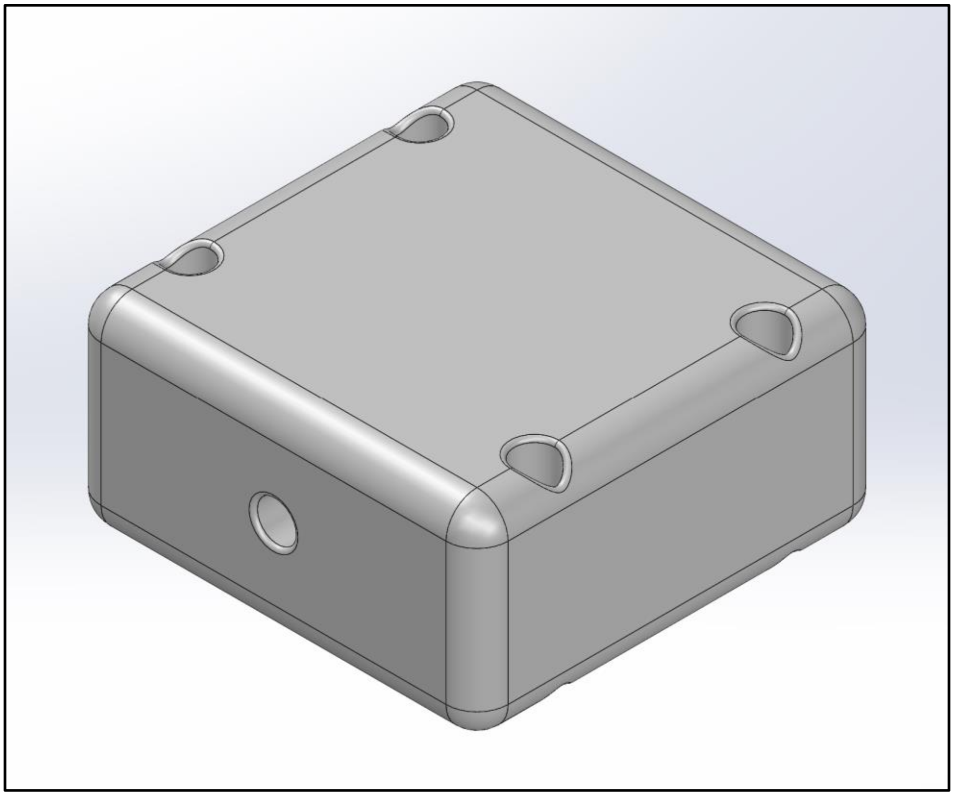
Right View



Top View

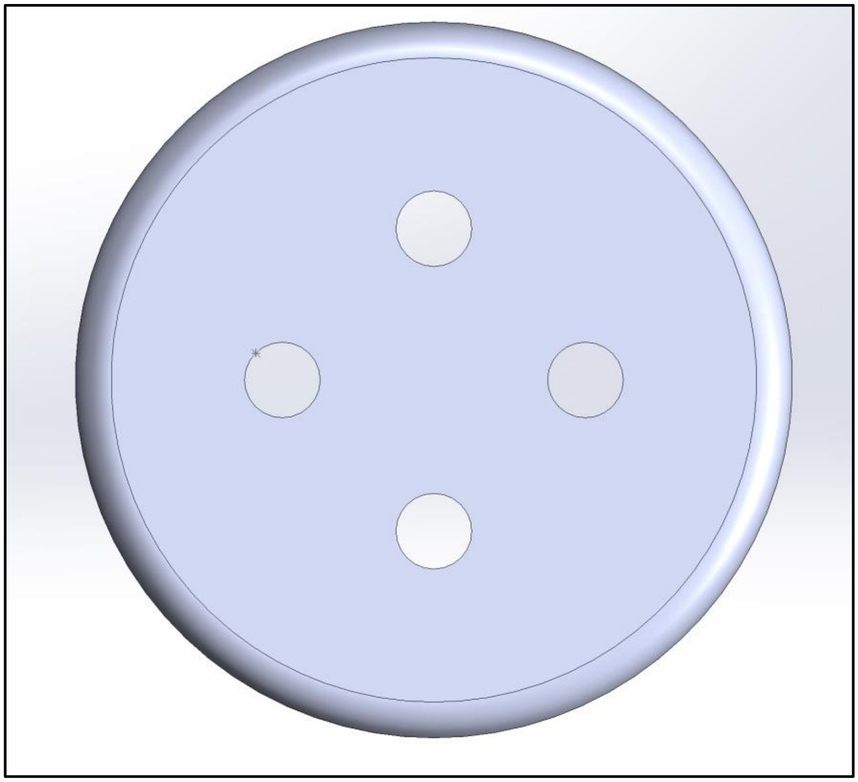


Isometric View

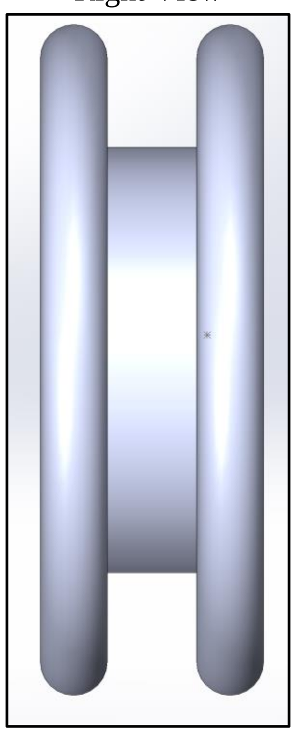


Spool Subassembly:

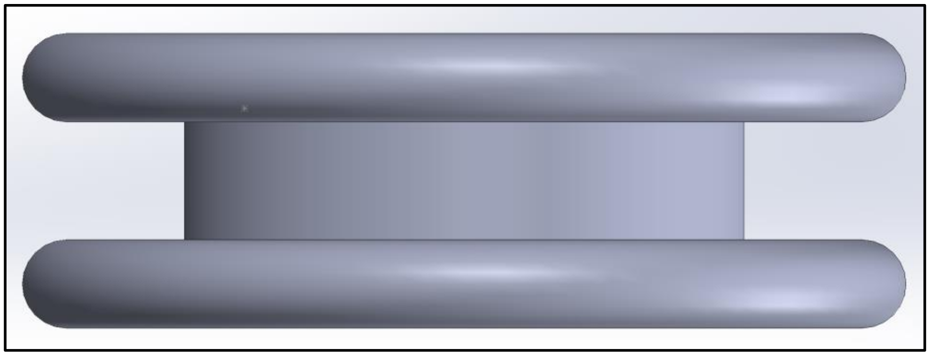
Front View



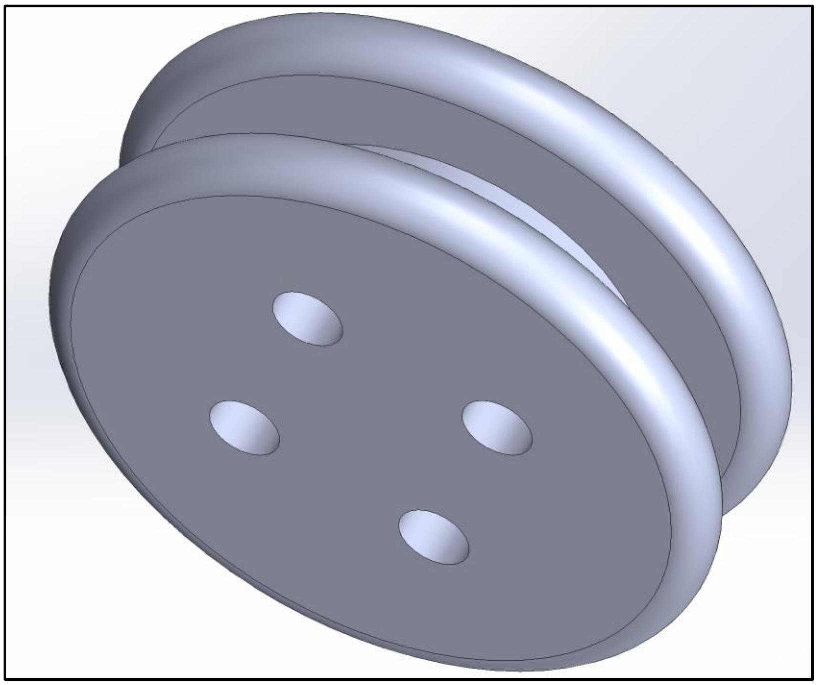
Right View



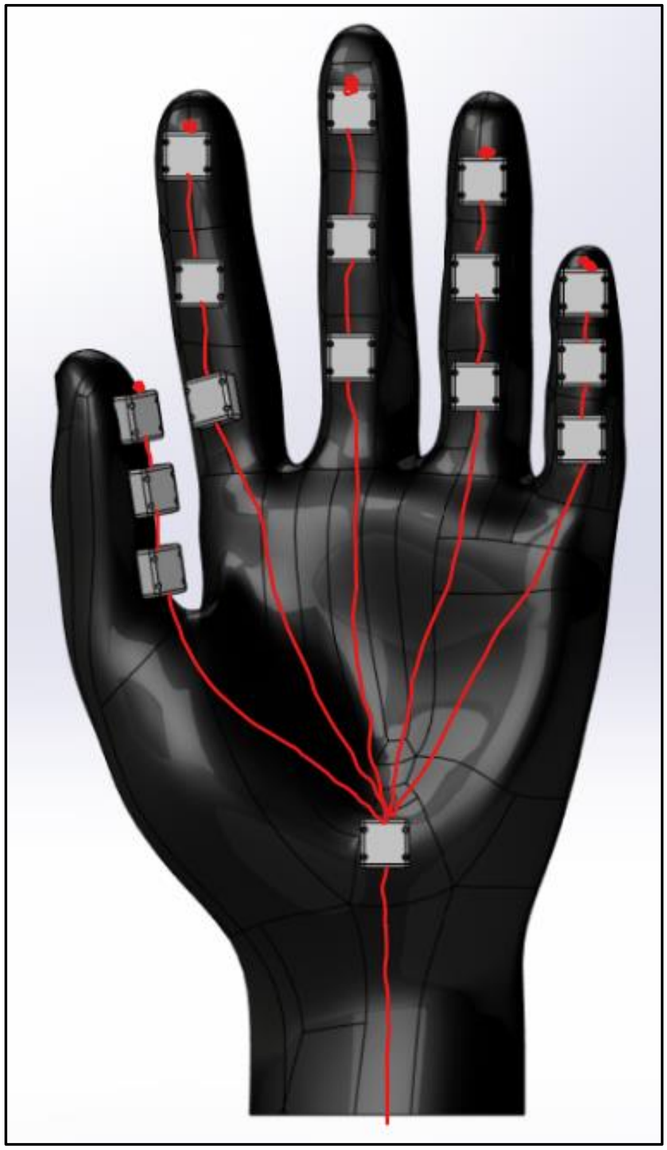
Top View



Isometric View



c.) As seen in the image below, the strings will run through each node on each individual finger. At the tips of the fingers the strings will be tied off to ensure that the string can not fall through the nodes. At the base of the palm all of the strings will meet at a single node which will feed to the motor spool. As the user pushes the “wind” button, energy will be transmitted from the battery to the motor, which will slowly rotate and wind up the string, which will shorten the string's length, therefore forcing the fingers to contract/close. As the user pushes the “unwind” button the motor will rotate in the opposite direction and unwind the string, therefore allowing the fingers to open. In a final prototype, each finger will have elastics built into them to ensure automatic uncurling of the fingers when unwinding the glove.



Note that the motor spool is not visible in this image, the motor spool will be mounted to the motor, which will be mounted on the forearm

Testing with FEA

Our subassembly of the glove is shown below, where we have placed each node at their approximate appropriate location.

Figure 3: Subassembly

We decided to conduct our FEA Analysis on the orientation above. In this orientation, the nodes will be experiencing the most amount of force, with the fishing line pushing against inner wall of the node in order to close the hand. For the analysis, we used the maximum force that the motor can output, which is approximately 25N. We then conducted the FEA Analysis which is shown below.

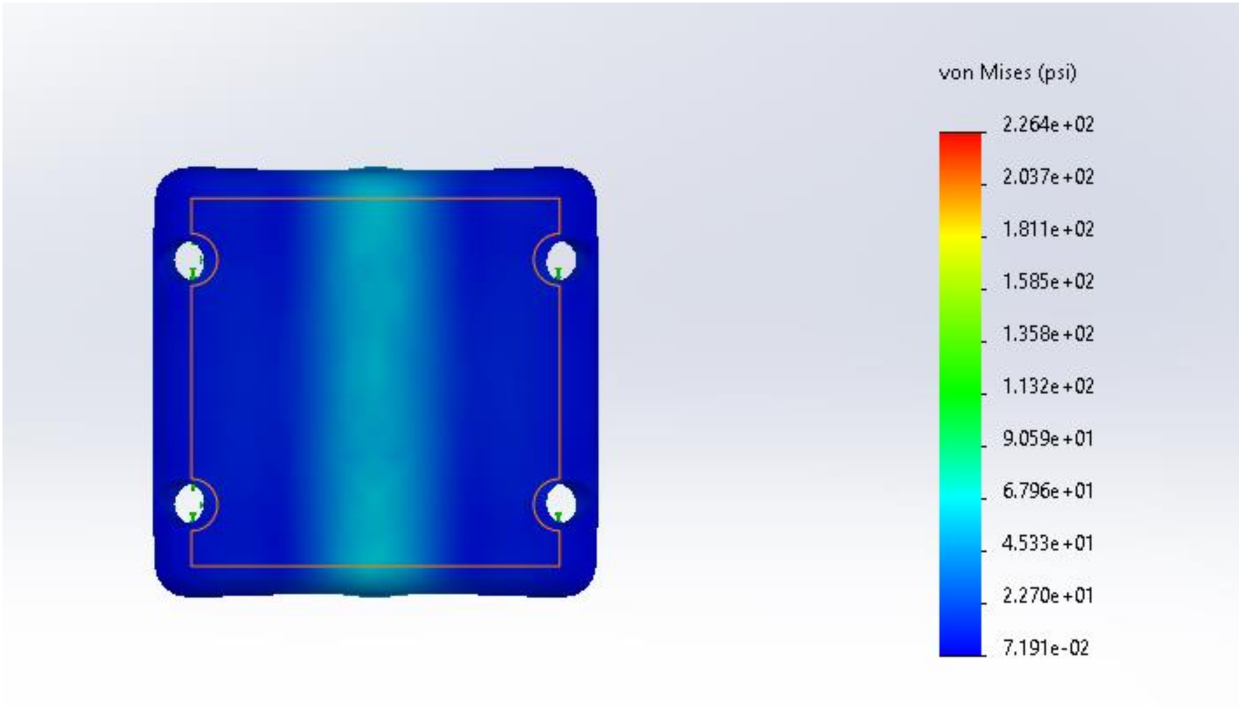


Figure 4: FEA Analysis for Stress

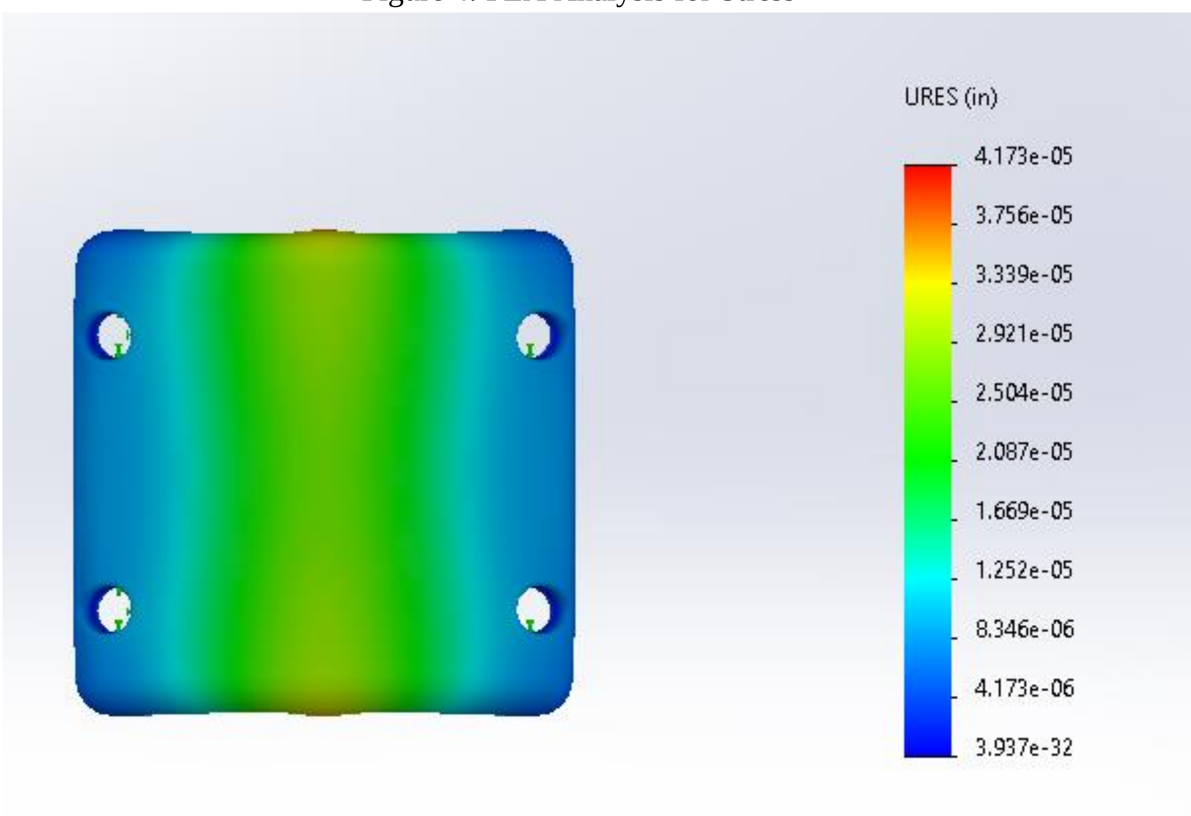


Figure 5: FEA Analysis for Displacement

As shown above, in Figure 4, the nodes experience very minimal stress, demonstrating a very high factor of safety. Furthermore, as shown in Figure 5, the nodes displace a very negligible amount out of the plane. This result is very similar to our hand calculations, where we show that there is barely any stress acting on the nodes with a very small displacement. The FEA Analysis should provide a better representation of the physical prototype since it takes into account multiple stress concentrations such as the holes and fillets. These are not fully taken into account in our hand calculations which make the calculations somewhat inaccurate to its real-world counterpart.

Manufacturing and Drawing

a.)

Finger Nodes:

These nodes are quite small and undergo very low stresses, so we decided to make these out of PLA plastic. PLA has a yield strength of 60MPa, and the nodes will experience a maximum load of around 10 kg to grip everyday objects.

We will be manufacturing the finger nodes via 3D printing with PLA. This will be the most lean manufacturing method and the cheapest for this prototype. Knowing that the cost to 3D print in techspark is $0.50/g and that each node weighs about a gram, we see that the cost to manufacture one node is about $0.50. The cost to manufacture enough nodes for the whole assembly would therefore be $8. Finally, assuming we manufacture 30,000 gloves per year, the cost would be $240,000. Note that in bulk we would likely switch to injection molding as our manufacturing method to reduce cost.

Palm Node:

This node is very similar in geometry to the finger nodes, except that it has a wider through hole to support 5 strings passing through it. We decided to make this part out of PLA due to its low cost.

We will be manufacturing the palm nodes via 3D printing with PLA. This will be the most lean manufacturing method and the cheapest for this prototype. Knowing that the cost to 3D print in techspark is $0.50/g and that the node weighs about a gram, we see that the cost to manufacture one node is about $0.50. The cost to manufacture enough nodes for the whole assembly would also be $0.50 because you only need one palm node per glove. Finally, assuming we manufacture 30,000 gloves per year, the cost would be $15,000. Note that in bulk we would likely switch to injection molding as our manufacturing method to reduce cost.

Motor Spool:

The motor spool will only experience compressive forces and internal moments, which will be less than or equal to 2.8kg*cm. Again due to the low cost and sufficient yield strength, we will manufacture this part out of PLA.

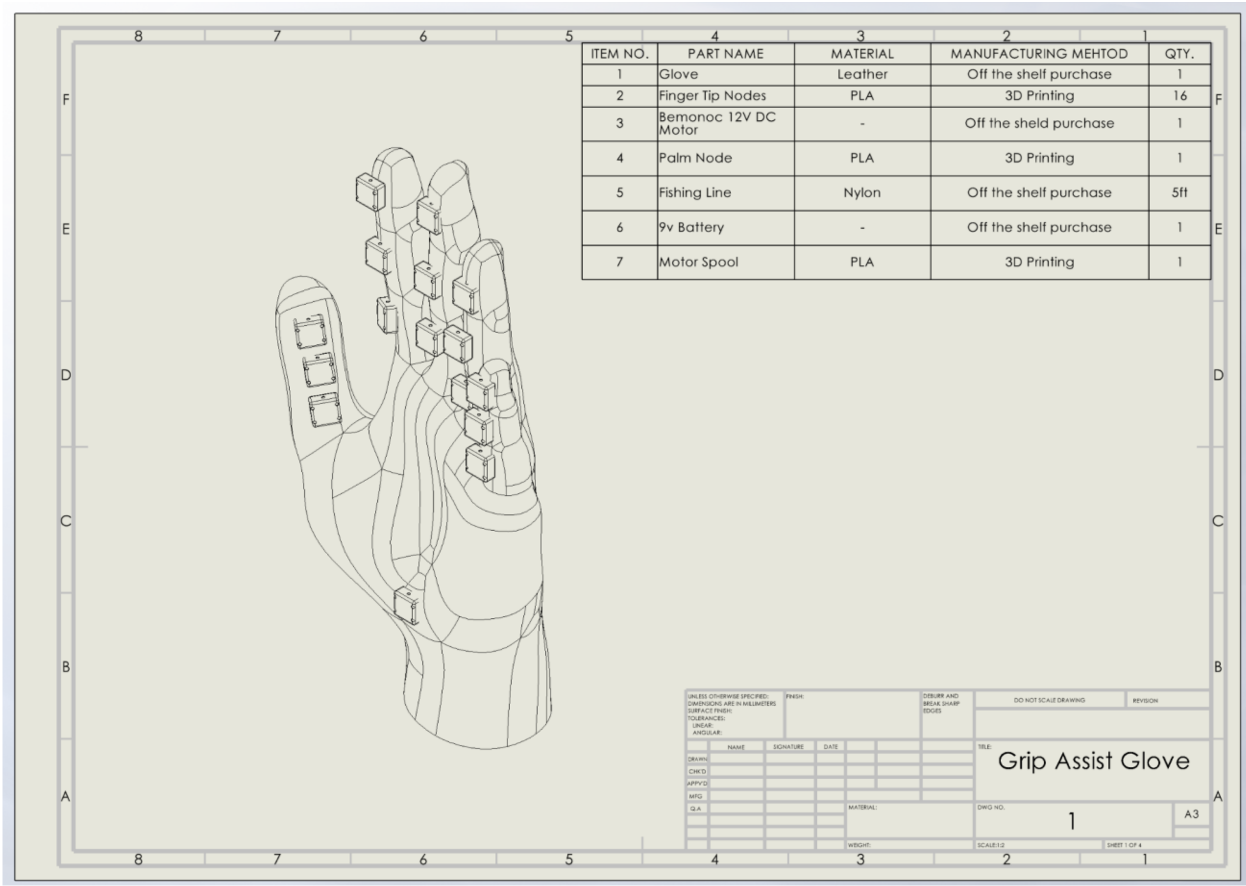
We will be manufacturing the motor spools via 3D printing with PLA. This will be the most lean manufacturing method and the cheapest for this prototype. Knowing that the cost to 3D print in techspark is $0.50/g and that each spool weighs about 5g, we see that the cost to manufacture one spool is about $2.50. The cost to manufacture enough spools for the whole assembly would therefore be $2.50. Finally, assuming we manufacture 30,000 gloves per year, the cost would be $75,000. Note that in bulk we would likely switch to injection molding as our manufacturing method to reduce cost.

b.

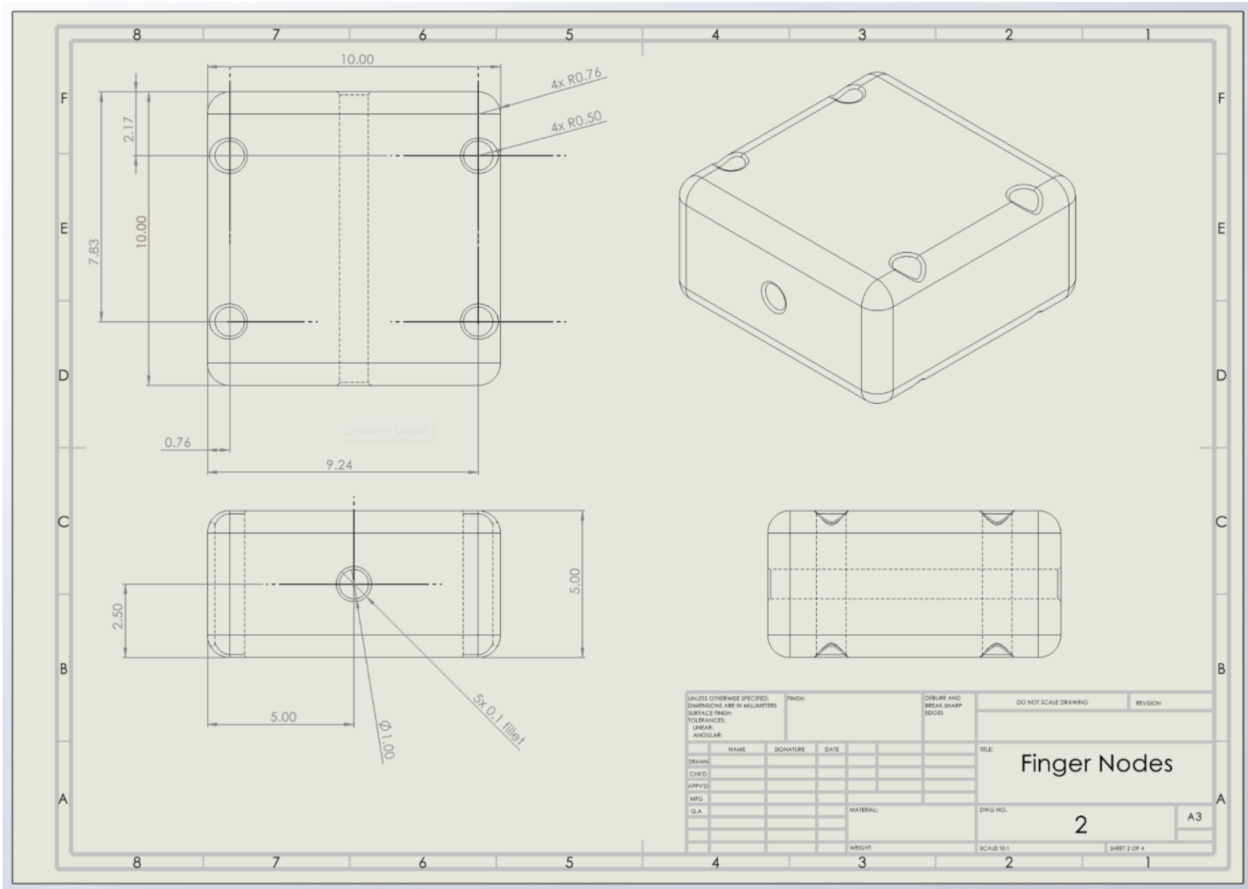
Part	Material	Manufacturing Method	Cost per Unit	Cost per Main Assembly	Cost per Year
Finger Node	PLA	3D Printing	$0.50	$8	$240,000*
Palm Node	PLA	3D Printing	$0.50	$0.50	$15,000*
Motor Spool	PLA	3D Printing	$2.50	$2.50	$75,000*

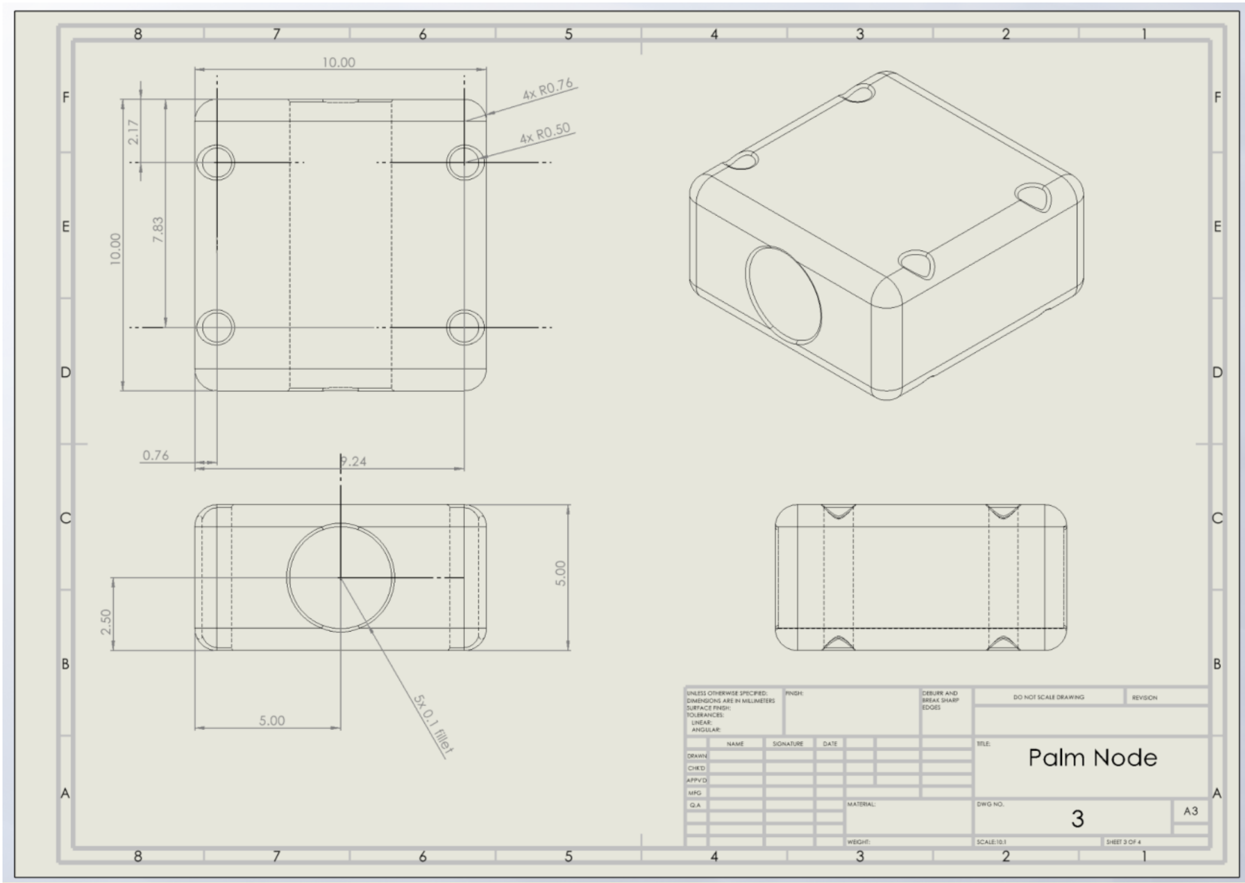
*To reduce cost in mass production we would use injection molding as the manufacturing method

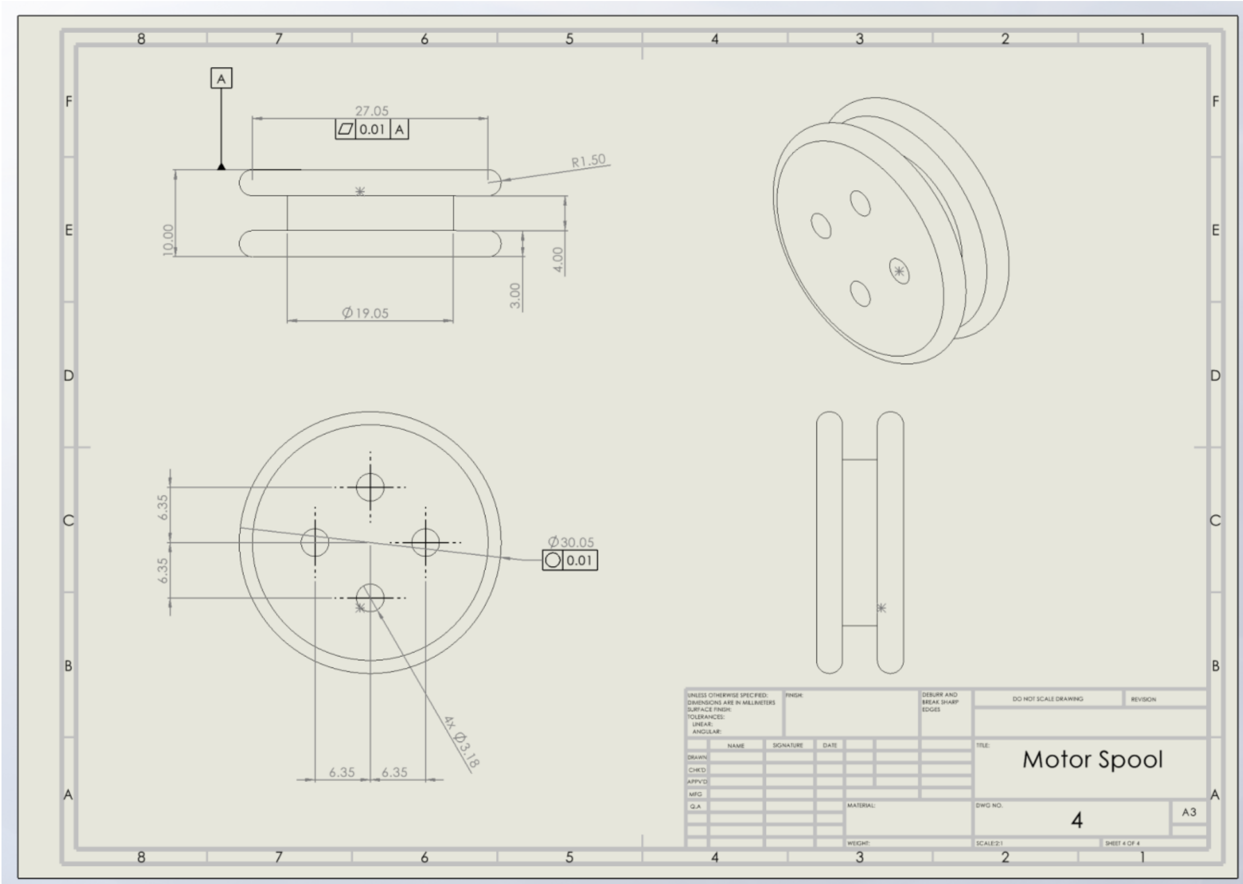
c/d.



ITEM NO.	PART NAME	MATERIAL	MANUFACTURING MEHTOD	QTY.
1	Glove	Leather	Off the shelf purchase	1
2	Finger Tip Nodes	PLA	3D Printing	16
3	Bemonoc 12V DC Motor	-	Off the sheld purchase	1
4	Palm Node	PLA	3D Printing	1
5	Fishing Line	Nylon	Off the shelf purchase	5ft
6	9v Battery	-	Off the shelf purchase	1
7	Motor Spool	PLA	3D Printing	1


10.00
4x R0.76
4x R0.50
2.17
10.00
7.83
0.76
9.24
5.00
2.50
5.00
Ø1.00
5x 0.1 fillet
Finger Nodes
2
A3


10.00
4x R0.76
4x R0.50
2.17
7.83
10.00
0.76
9.24
5.00
2.50
5.00
5x 0.1 fillet
Palm Node
3
A3



e. The cost of the base glove is $11 ($6.50 for one glove), the cost of wire was $8 for 375y, which is enough for 75 gloves, which means the cost of wire per glove is $0.11. The cost for the palm node is $0.50. The cost for the motor spool is $2.50. The cost for the electronic components including the motor is $26. This means the total cost for manufacturing the glove is $35.61. Adding in a 30% markup, the end product cost to a customer would be around $46.30.

Budget

a.

Vendor	Description	Link	Quantity	Unit Price	Shipping	Subtotal
Amazon	Leather Gloves	https://www.amazon.com/dp/B07YWR1JP2?ref_=cm_sw_r_apin_dp_W1EPSY3R6JPVHTZJ0KGG	2	$10.99	n/a	$21.98
Amazon	Push Button Switch	https://www.amazon.com/Twidec-Colors-Momentary-Pre-soldered-PBS-110-X6C/dp/B07RTZVZ6L/ref=sr_1_4?keywords=arduino%2Bbuttons&qid=1681308318&sr=8-4&th=1	1	$10.97	n/a	$10.97
Amazon	Fishing Line	https://www.amazon.com/Berkley-Trilene-Game-40lb-370yd/dp/B00144EWXW/ref=sr_1_7?keywords=40+pound+fishing+line&qid=1682739574&sr=8-7	1	$10.99	n/a	$10.99
						$43.94 Total Spent. $156.06 Remaining Budget.