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BMME 310

Group 1: Final Project Report

1. Introduction

1.1 Context

The Helping Hand Project at UNC Chapel Hill is a non-profit organization which creates 3-D printed hands, designed and assembled by students, for children in need. Juniors majoring in biomedical engineering were tasked with creating custom prosthetics for Helping Hands clients. Our team, group 1, designed a prosthetic for Valeria's left arm, pictured in fig 1 below.

Figure 1 Valeria's left arm—the arm of interest.

1.2 Intent

The ideal prosthetic would elongate Valeria's arm to the length of her functional arm (~14 inches), as well as provide digit flexure. The design should provide four fingers and a thumb for increased dexterity, as Valeria is missing a thumb and pinky finger.

This was accomplished through both an upper and lower arm extension (each 7 inches in length) and a hand capable of thumb and four finger flexure. The prosthetic utilizes her current capabilities (some finger dexterity), to actuate the device: Valeria will trigger hand flexure with easy-to-use push button switches. The prosthetic interfaces with the client by attaching to her upper arm via Velcro straps, and her fingers will rest on a smooth plane embedded with the switches, which will be attached to an upper arm cuff. The technical aspects of the design are described in full detail in section 2.

2. Design Philosophy

2.1 Fingers and Palm

The prosthetic fingers are engineered for life-like flexure. Two holes are included in the posterior face of each finger to allow for thick, durable paracord to be looped through the entire extremity. Two holes are located on the anterior face of each digit. Fishing wire runs through these holes, seen below in fig 2. When the fishing wire is pulled, the fingers move downward, allowing for life-like contraction.

Figure2 Fishing wire, which acts as a tendon, running through the anterior face of the fingers.

From the holes in the finger, the fishing wire runs through the entirety of the palm, through vertically aligned holes at the base of the palm, into the forearm, and is subsequently attaches to s servo motor. The base of the palm has screw holes aligned with the holes in the forearm for easy attachment. ¼-20 imperial bolts were used to fasten these pieces together. The aligned bases of the forearm and palm are depicted in fig 3 below.

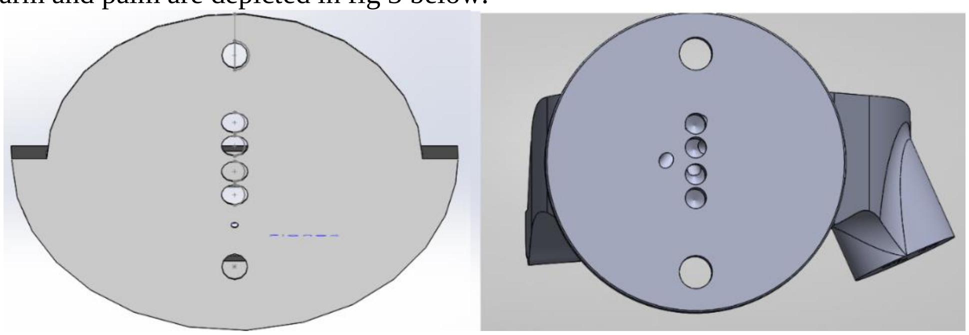

Figure 3 Bases of the lower arm (left) and palm (right) aligned.

2.2 Forearm and Cover

Five holes at the superior face of the lower arm align with the five holes at the base of the palm to allow for the fishing wire to reach the servo motor embedded in the lower arm. There is housing for the motor, floored with Velcro, to keep the servo secure while in use, as seen in fig 4. The velcro also allows for the servo to be easily removed should it fail. There are also holes for M6 machine screws, as seen in fig 4 below. These holes hold the hinge in place so the arm can hold position at different angles.

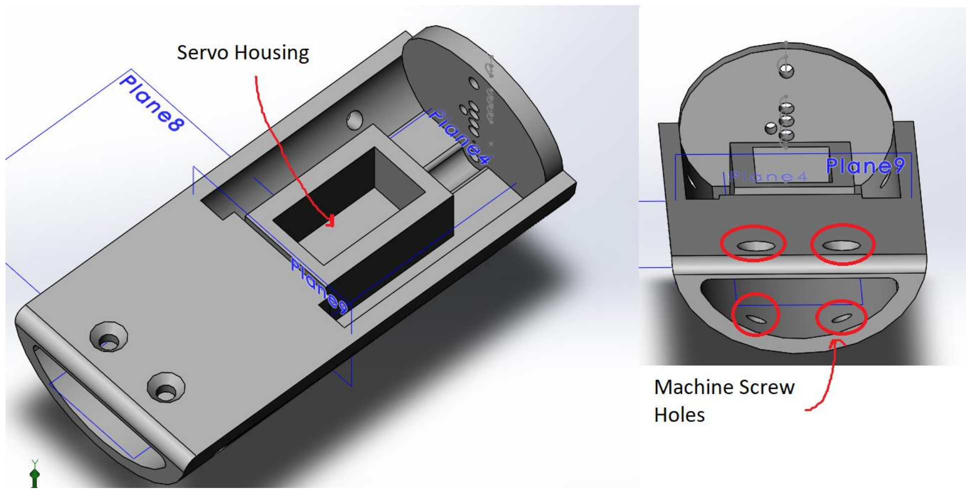

Figure 4 Left image: Lower arm with servo housing. Right image: Lower arm with holes for M6 machine screws.

A cover was created and attached with Velcro to the lower arm. This cover ensures the electronics will be effectively isolated from the client.

2.3 Elbow Joint and Upper arm

The elbow joint (fig 5) consists of a bracket. This will allow for a ~0˚-70˚ range of motion for the arm. The client will have a more life-like experience if she is able to maneuver and lock the arm at several different orientations.

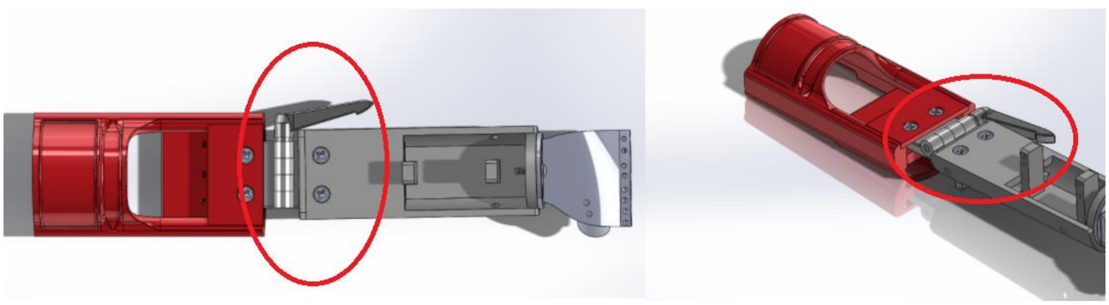

Figure 5 Lower arm to upper arm hinge.

The client’s upper arm will be fastened to the red piece with Velcro. Her fingers will rest on the bottom surface of the arm cuff. A button will also be secured on the bottom surface; when the client pushes the button, she will activate the electronics.

2.4 Electronics

Thumb and finger flexure are electronically actuated. The process is initiated with a SPDT switch. The button is placed on the upper arm cuff where Valeria’s hand will rest, for easy access. When Valeria first presses this button, she will close a circuit, connecting 5V to pin D7 on the Arduino Nano microcontroller board[1]. This sets D7 to “high”, notifying the servo at pin D6 to rotate 180˚. When the button is pressed again, D7 is connected to 0V, goes “low”, and the servo returns to 0˚. The 9V battery serves as the input voltage for the microcontroller and servo — regulated by a 3.3V voltage regulator. Pre-written C code, summarized in fig 6 below, dictates the circuit’s behavior. Fig 7 below is a schematic of the circuit.

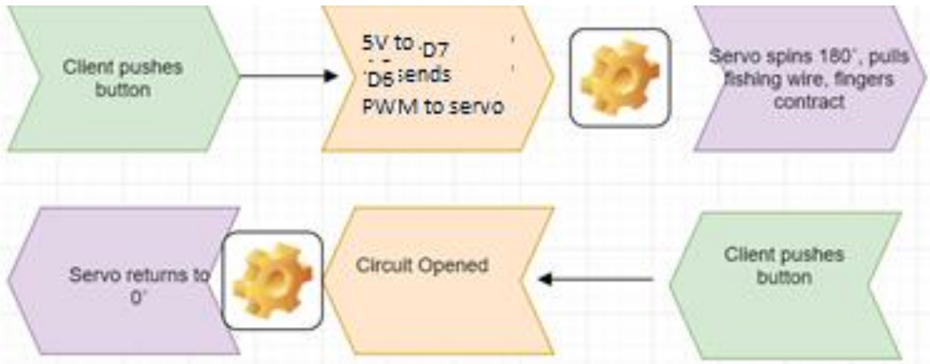

Figure 6 Circuit flowchart for electronic actuation.

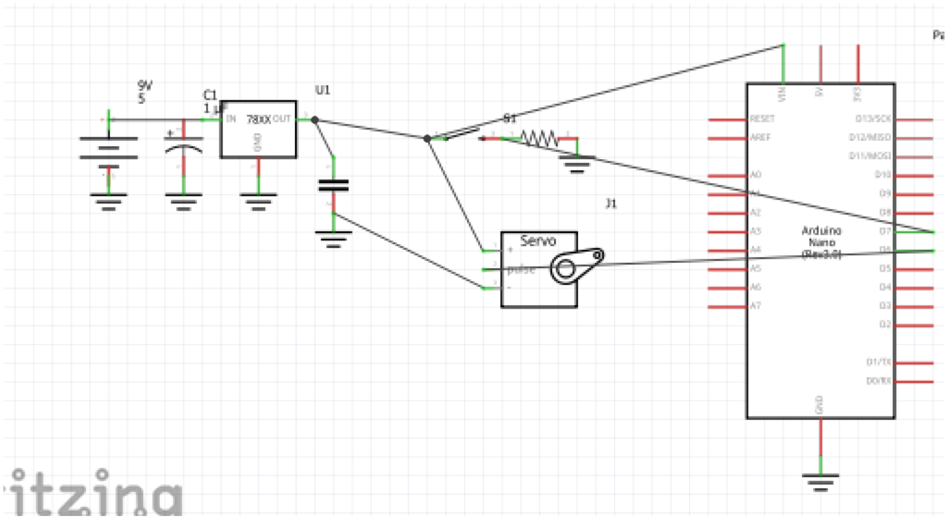

Figure 7 Circuit schematic for driving servo motor.

3. Manufacturing and Materials

3.1 Parts and Materials

Fig 8 below summarizes all parts made/used for the hand. The hand itself was created from CPE: and 3-D printed from Ultimakers.

Bill of Materials

Category	Part Name	Part # / Product ID	Manufacturer	Quantity	Cost/unit (USD)	Notes
Bulk Material	CPE (co-polyester)	596490ba34110	Ultimaker	12.8 in^3	0.353 * $59.95 = $21.16	Link: https://ultimaker.com/en/products/materials/cpe
Electronics	Arduino Nano	1010993	Arduino	1	$22.00	https://store.arduino.cc/usa/arduino-nano
	9V Battery	2224	Amazon	1	$5.00	Amazon.com
	JX PDI-6221MG 20KG Large Torque Digital Standard Servo	973947	JX	2	$11.99	Link: https://www.banggood.com/JX-PDI-6221MG-20KG-Large-Torque-Digital-Coreless-Servo-For-RC-Model-p-973947.html
	SPDT Switch	DEV-08776	Sparkfun	1	$1.50	Link: https://www.sparkfun.com/products/8776
steners + connective pie	2x 1/4" 20 imperial screws + nuts	1170005	Fastenal	2	1/100 * $7.17 = $0.07	https://www.fastenal.com/products/details/1170005
	#6 countersunk machine screw	9804		2	4.52	https://www.boltdepot.com/Machine_screws.aspx
	Spiderwire Braided Stealth Superline (fishing wire)	1339718-P	Spiderwire	1	$6.86	Link: https://www.amazon.com/Spiderwire-SCS6G-125-SpiderWire-Stealth/dp/B00LDYMA28/ref=sr_1_9?s=hunting-fishing&ie=UTF8&qid=1507417770&sr=1-9&keywords=fishing+line
	Black - 1/8 Shock Cord	10 X PAR-18SC-BLACK	Paracord Planet	1	$4.99	Link: https://www.paracordplanet.com/black-1-8-shock-cord/?gclid=CjwKEAjwoPG8BRCSi5uu6d6N5WcSJABHzD8F0L0fHDhT_dqwNNAAP0UubP1OmgCBMNTkp_OyXJ0xuBoC05Tw_wcB
	12"x12" Adhesive-Backed Food-Grade Multipurpose White Neoprene Rubber Sheet	1340N21	McMaster-Carr	1	$11.77	Link: https://www.mcmaster.com/#standard-rubber-sheets/=19rp7uw
	5ft x 1in Plain Backing Black Multipurpose Hook and Loop strips	9273K52	McMaster-Carr	3	$4.66	Link: https://www.mcmaster.com/#hook-and-loop-fasteners/=19rp8vd
	Original Gorilla Glue, 4 oz., Brown	5000408	Gorilla	1	$5.97	Link: https://www.amazon.com/Gorilla-Original-Glue-oz-Brown/dp/B0001GAYRC

Figure 8 All manufactured/bought parts for arm.

4. Conclusions

4.1 Future Improvements

This project was ultimately a prototyping experience, and thus the design is flawed. If time allowed, certain changes could be made to improve the device. There are two main areas of concern: The elbow joint and weight.

4.1.1 Elbow Flaws

Specifically, the design philosophy behind the elbow is flawed. At first, there was going to be separate elbow flexure with a second servo motor. This would allow for a wide range of movement. This, however, seemed beyond the scope of a semesters-worth of work. The design team then considered assembling the arm at a permanent 90˚ angle. This did not seem very helpful to the client upon further inspection. In the end, a bracket was used to allow for the arm to move from a straight (0˚) position, up to ~70˚. The bracket is lockable, so the arm can be held at the desired position, as shown in fig 9 below.

Figure 9 The arm locked at ~55˚.

While the use of the bracket allows for a reasonable range of motion, there are two areas of concern. First, the bracket places stress on the forearm (blue piece) where it is attached. When locked in tension, the plastic bears the load of the entire arm. With repeated use, this could lead to cracking. To account for this, the forearm was printed at 60% infill and is more durable than the other pieces, but stress fracturing is still a risk.

The second concern with the bracket is usability. While she could do it with her functional arm, Valeria would have trouble locking the bracket in place. This makes the device less user friendly and less than ideal.

If more time were available, an elbow mechanism that did not stress the plastic and require external locking would be used.

4.1.2 Weight Concerns

While Helping Hand's cases generally require small extensions, Valeria's case was difficult, as she required an entire arm prosthetic. Because the prosthetic had to total ~14 inches in length to improve the client's functionality, it is concerningly heavy. Most pieces were printed at 20% infill to reduce weight concerns. The forearm, however, has to bear considerable load and was printed at 60%, which increased its weight. Factoring in electronics and fasteners, the prosthetic is heavier than necessary. To combat this, a Velcro harness could be made to distribute the weight of the arm. The design could also be altered to remove excess material.

4.1.3 Small Changes

Some of the engineering practices used in prototyping were of bad form. For example, Imperial and metric fasteners were mixed. This is not desirable for a manufacturer who would have to order both parts, reducing the design's marketability.

In retrospect, more care could have been taken during the design phase. Numerous re-prints had to be made due to small errors (eg. bolts not fitting). This could have been avoided with greater attention to detail.

4.2 Next Steps

Upon completion of the prototype, the aforementioned changes should be implemented. After product improvements are complete, the client should test the device and give feedback so it can be altered to better suit her needs.