Design Project 4 – Not a Pun, It's Real Life

RehabiliMate – *Grasp the Future*

IBEHS 1P10 – Health Solutions Design Projects

Tutorial 1

Team 7

Aizah Malik (malia48)

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Saanvi Sood (soods10)

Ahmed Zafar (zafara19)

Submitted: April 8th, 2024

Course Instructors: Dr. McDonald and Dr. Sask

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Academic Integrity Statement

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Deepam Patel 400529944

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

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The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Saanvi Sood 400516356

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Aizah Malik 400539949

Main Body

Summary of Design Objectives

Need Statement:

Design a rehabilitation device for Heather, a 58-year-old multiple sclerosis patient, experiencing a significant decline in motor skills, particularly in her left hand. This rehabilitation device will aid in re-training her affected hand in order to help her regain its dexterity, increasing her quality of life, and independence making her day-to-day life easier, and more convenient.

Customer Requirements	**Type**
The patient highlighted the constraint of non-restrictive. Heather was clear in expressing that the device should not make her 'feel like a robot', essentially meaning the device should not make her feel estranged and alienated when in public.	Note highlighted by the patient.
Design should be non-restrictive. Should not hinder her mobility any further.	Constraint
Design should improve some or all of the following: quality of life, mobility and independence of Heather.	Objective
Design MUST be safe and SHOULD NOT worsen her condition.	Constraint
Design should not be ‘flashy’ and make her ‘feel robotic’.	Constraint
Design should be easy and intuitive for Heather to use.	Objective
The design should be comfortable for Heather to use, as to minimize any strain on her body while using the device.	Objective
If applicable, the device should integrate into any devices Heather currently uses.	Objective
The device should be relatively portable, easy to store and transport, in order to allow use of the device during her travels.	Objective

Description of Proposed Solution

Heather is a multiple sclerosis patient whose spasticity in her left hand involuntarily curls her fingers. Despite hand rehabilitation being a more effective treatment of spasticity than the splinting methods Heather has tried [1], she has never received any dynamic rehabilitation for her hand.

Figure 1: Phases of hand straightening, from Heather's natural curled position (rightmost) to fully straight (leftmost)

Effective rehabilitation relies on targeting the correct movement(s), in addition to consistency [2]. For Heather, the movement she must target is the straightening of her hand, shown in Figure 1. However, the hand spasticity makes it so that she cannot straighten her hand without individually uncurling each finger. Due to this, manual attempts to straighten her hand do not accurately simulate straightening her entire hand. Therefore, Heather requires targeted assistance to facilitate her rehabilitation. One option would be to visit a physiotherapist. Since the hand rehabilitation Heather needs requires a daily regimen [1], having this need met by physiotherapist visits would be very expensive and time consuming [3].

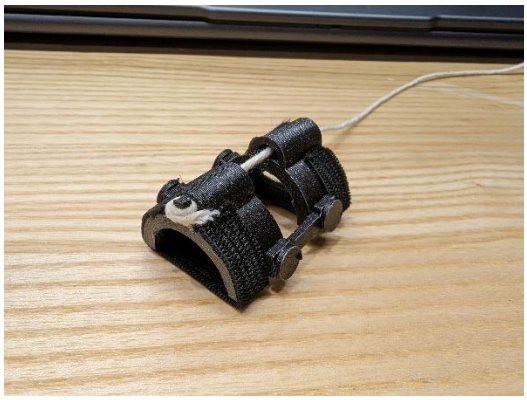


Figure 2: Image of finger components assembled before being put onto the glove.

Integrating an exoskeleton and a computer program, RehabiliMate allows Heather to rehabilitate her hand from the comfort of her home. As can be seen in Figure 2, the finger segments are connected across the joint by a set of hinges and bolts. This design allows for the straightening or curling of the finger mechanism to straighten Heather's fingers. Figure 2 also demonstrates how the finger components have arches that allow for a string to be passed through, with the higher component having a knob to allow for string fixation.

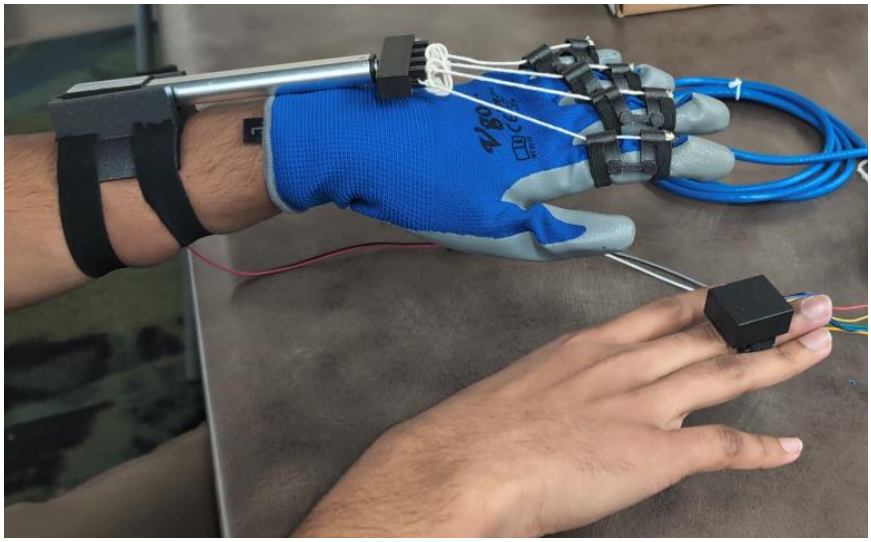


Figure 3: Image showing entire RehabiliMate mechanism. In order from left to right, the left hand has the linear actuator housing, the linear actuator itself, the linear actuator adapter, the connecting strings, and four sets of the finger components. The right hand has the orientation sensor and housing positioned on the middle finger.

This string is tied back onto the hooks of the front side of the adapter shown in Figure 3. The adapter is designed to have a friction fit with the end of the linear actuator on the other side. Figure 3 also shows a housing that allows for a friction fit with the other end of the linear actuator that has elastic and Velcro to allow for a customizable positioning on the arm. On her able right hand, the container pictured in Figure 3 allows for placement of an orientation sensor on Heather's finger. The use of elastic straps on the finger components and linear actuator housing shown in Figure 3 allow for the device to suit a wide variety of hand shapes and sizes while the glove allows for the finger components to be slipped on in one go.

In "Reaction-Potential" mode, the orientation sensor controls the actuator. For example, the code will retract the actuator and straighten her left hand if the sensor receives input that Heather's right hand is straightening. Through this mode, Heather can see the movements of her right hand mirrored by her left. This strengthens the mind-muscle connection that is vital to the success of rehabilitation [4]. It also

ensures that Heather is an active participant in her regimen. An interactive GUI gamifies the experience and encourages Heather to be consistent in her rehabilitation.

Through this design, RehabiliMate offers a novel and home-based way of treating Heather's hand spasticity to help her grasp her future!

Summary of Design Process

The initial dilemma faced when designing RehabiliMate had to do with the preliminary idea generation. There were many ways to approach the problem. After much consideration was given to brainstorming, and sketching, the solution started to converge to a single sketch (Figure 4).

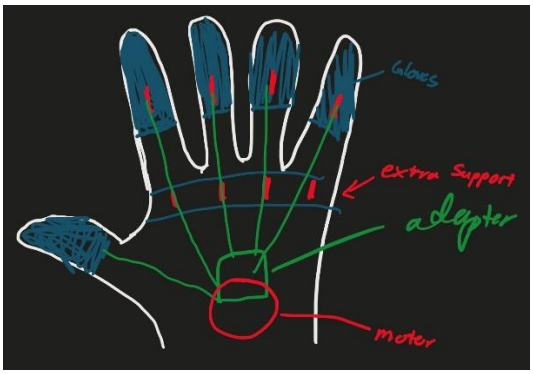


Figure 4: Initial Sketch of design.

The first design included a DC motor that would pull on the fingers via cut outs of glove fingers. Included in the design, was a band of extra support along the back of the upper palm. Finally, the fingers were pulled back by elastics that were projected to be glued in various places. This design led us to our initial prototype (Figure 5), where some changes were made during the assembly process.

Figure 5: Initial prototype of RehabiliMate.

Constructing the low fidelity prototype prompted changes such as employing rings rather than cut off sleeves to maximize the tension forces felt (a sleeve would be prone to sliding, losing efficiency), adding a wrist support to house the motor, and removing the additional supports as the rotational forces and varying directions would not align with the supports.

Figure 6: The second low fidelity prototype.

After a design review and outsider perspective was given, more insight was given to the comfort and ease of use of RehabiliMate. A sheet of cloth was fastened along the bottom to allow the user to easily slide their hand into the mechanism and begin their physiotherapy as seen in Figure 6. It also became clear that using a motor would not be feasible as it produced uncomfortable rotational forces on the fingers, and the precision of the motor was often hard to predict. With the low-fidelity prototypes completed, and any obvious issues averted, the ideation and specifics of the mechanism began.

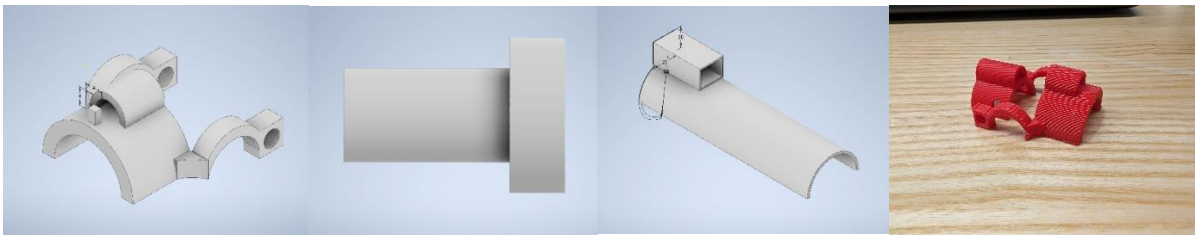


Figure 7, Figure 8, Figure 9 Figure 10: Initial CAD Design of finger attachment, bolt, and linear actuator housing along the arm, and the 3D printed model.

The initial CAD included one hinge with a curved bridge to allow for a more natural curl of the hand, flat bolts, and a long arm attachment for the linear actuator. This design was riddled with flaws. Only having one hinge didn't allow for the complete closure of the hand (Figure 7), the straight bolts went through the model into the user's fingers (Figure 8), and the actuator housing was unnecessarily big (hindering comfort and flexibility) (Figure 9) and did not account for the attachment on the elastics to the actuator. Changes were made to all the parts. Additionally, the decision was made to omit the thumb from the design as we were limited to one linear actuator, and the thumb is on a different axis than the rest of the fingers. Finally, it was decided that tension would be provided by strings rather than elastic. This is because

the force from elastics varies with respect to the distance that they are stretched, making it more unpredictable and harder to comply to safety standards.

Hinge Mechanism:

As the most mechanical complex and intricate part of the design, the hinge mechanism required the most iterations and design alterations.

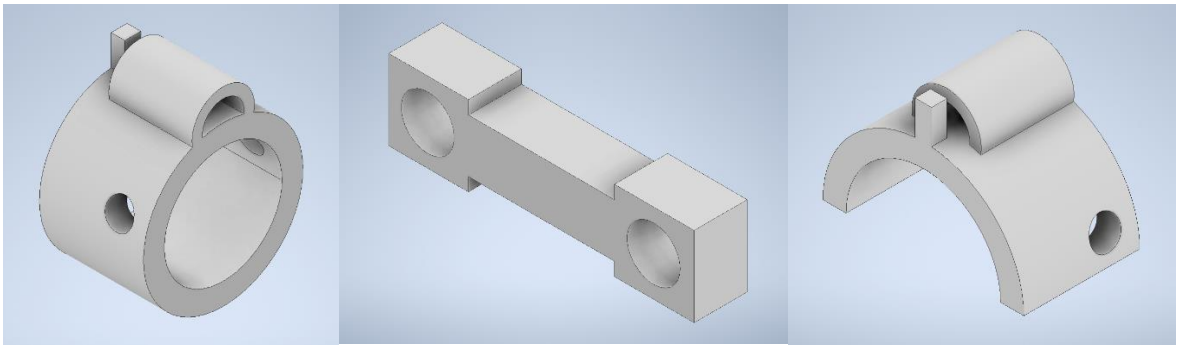


Figure 11, Figure 12, Figure 13: An intermediate ringed finger attachment, the detached hinge, and the final finger attachment.

Figure 11 displays an iteration made to highlight ease of use and comfort, as the mechanism would receive more control over the user's hand, however after printing, there was interference when the hand was bent and pinching of the finger caused pain. Furthermore, a ring design limited accessibility: the design would have to be custom made for individual users, rather than a one size fits all. Figure 12 shows the new separated bridge that replaced the curved bridge from the last iteration. This bridge allows two different degrees of rotation, while is more analogous to the natural motion of a closing hand. Figure 13 is the final design for the finger attachment. By removing the bottom half of the ring, elastics can be attached to allow for a product that works for a diverse range of users. The addition of using two sections, connected by the bridge is analogous to the idea of having additional supports on the back of the palm as seen in the initial sketch (see Figure 4).

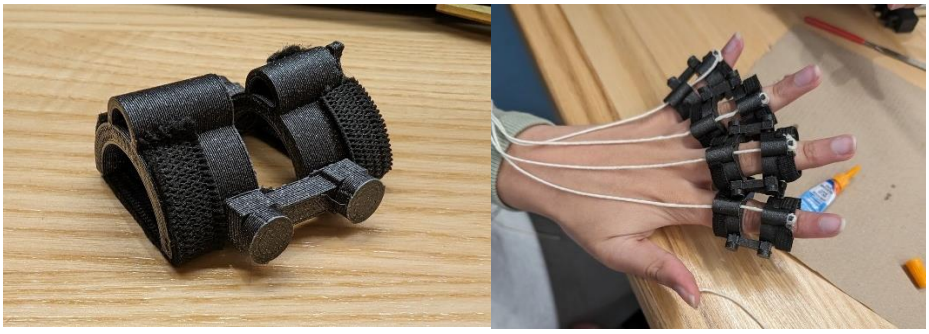


Figure 14, Figure 15: The printed design of the hinge mechanism, and a user wearing all four finger attachments.

The last and final addition to the hinge mechanism was found when printing this penultimate design. Due to the size of the bridge and the bolts (Figure 15), there was heavy interference between each finger. This was solved by making the bridges and the bolts thinner.

Bolts:

The bolts were the least problematic/easiest piece to design and perfect.

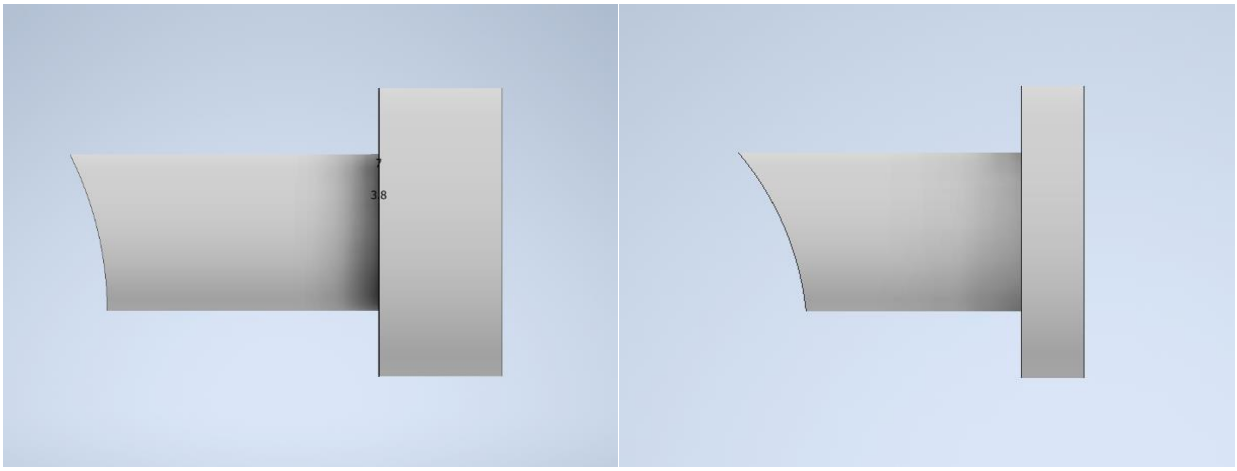


Figure 16, Figure 17: The initial alteration of adding a curved end, and the final design.

The bolt only underwent two iterations. The first iteration (Figure 16), added in a curvature to the bolt to eliminate discomfort felt by the user, and the final iteration made the head of the bolt thinner, to reduce the interference between adjacent fingers attachments.

Electronics attachments and housing:

Electronics of this project included the linear actuator, and the orientation sensor worn on the non training hand. The initial linear actuator housing can be seen in Figure 9.

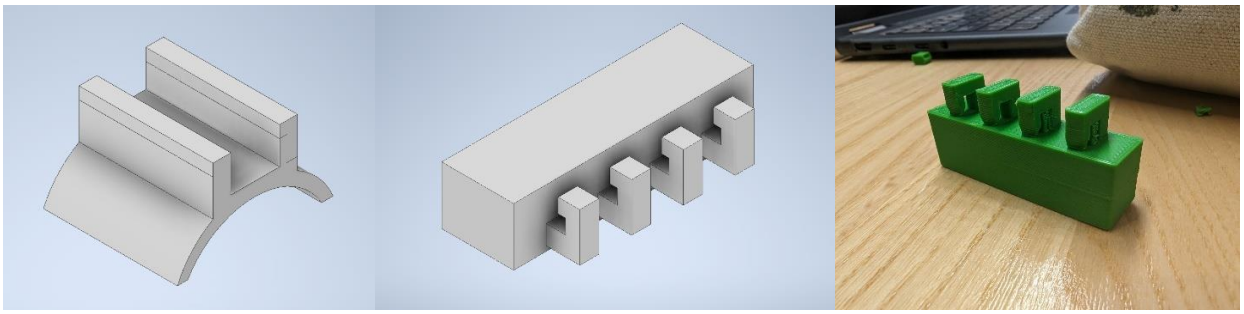


Figure 18, Figure 19, Figure 20: The updated design for the linear actuator housing, first prototype of actuator adapter, and the printed prototype of this adapter.

Figure 18 was the conclusive design for the linear actuator housing as this design fit the actuator and allows the user more comfort and flexibility of the arm. The design for the adapter seen in Figure 19 and Figure 20 was flawed. This was found as the strings fell off the hooks when tension was released.

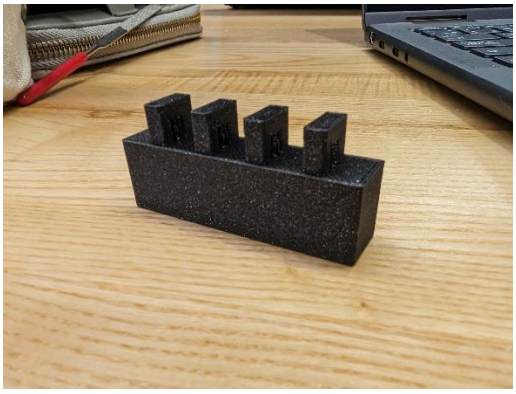


Figure 21: The printed copy of the final design of the linear actuator adapter

Figure 21 shows the final prototype of the adapter. It includes closed hooks around the tied strings to eliminate the scenario where the strings must be reattached, which would be significantly more difficult for someone with limited hand mobility.

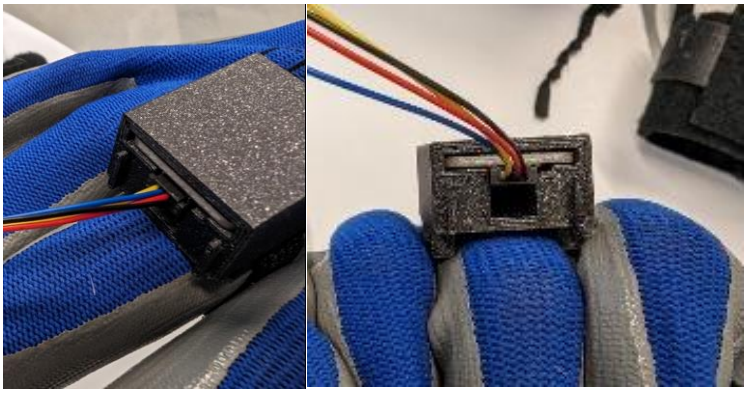


Figure 22, Figure 23: The printed copies of the sensor housing

The orientation sensor housing (Figure 22 and Figure 23) only had to be reprinted once as well, as the initial print did not include enough tolerance. This taught a lesson about the limitations of 3D printing, and the importance for tolerance when dealing with fragile technology. Elastics were added to the bottom to create a wearable ring to fit users of all sizes.

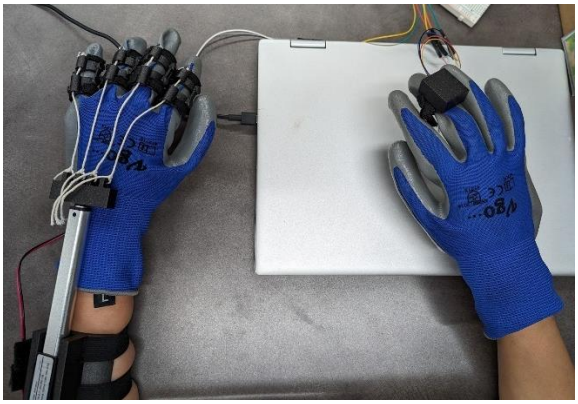


Figure 24: The finished mechanical product

Finally, for ease of use, gloves were added to the final design (Figure 24). This decision can be brought back to the lesson learned from the second prototype (see Figure 6), where additions were made to make the device easier to put on and take off as the intended user has extreme hand spasticity.

Software/Computing Design Process:

There were only three major changes or challenges to the code through the duration of the project.

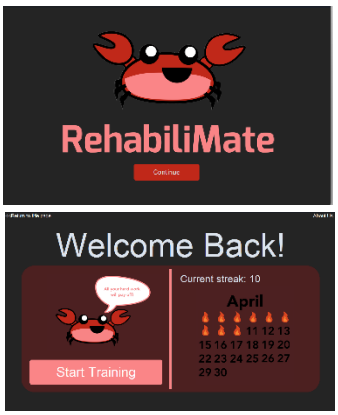


Figure 25, Figure 26, Figure 27: The initial shell interface, the title page of the GUI, the home page of the GUI.

The first iteration of the code came with a minor flaw. At the end of the day, our client may not be well-versed in running python script or understanding how an interactive shell such as IDLE works (see Figure 25). Instead, an Interactive GUI was coded to accommodate for this and create a more accessible and easier to use product (Figure 26, Figure 27). In doing so, the product could take advantage of gamification principles and fit better with our clients needs.

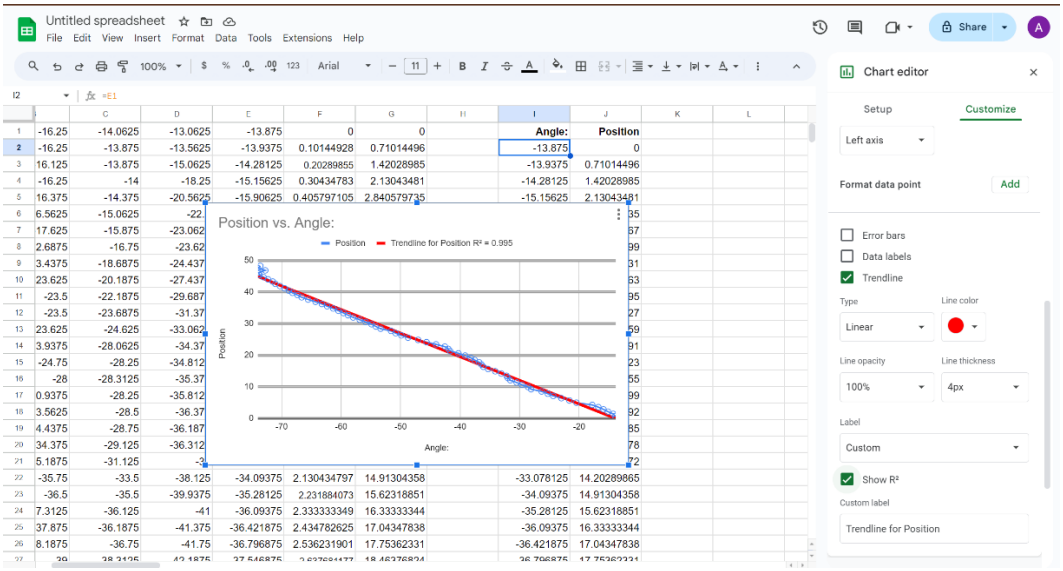


Figure 28: Experimental Data being modelled to create a more accurate equation that relates angle of sensor to linear actuator displacement.

The second major challenge that occurred with the code with the mirroring technology. Finding a way to translate orientation sensor data into the corresponding linear actuator position. Upon much trial and error, there was still no clear solution on what mathematical equation could be used to relate both quantities. To solve this challenge, four trail runs were conducted where the able-bodied hand followed the training hand at the same pace while the training hand was being pulled up by the mechanism. By pasting these values into Excel and using basic kinematics involving the constant velocity of the linear actuator, a linear equation could be derived to relate sensor angle to desired linear actuator position (Figure 28). This teaches a lesson about using resources whenever available.

The final challenge that had to be overcome on the software side of RehabiliMate involved the outputs of the orientation sensor. Under certain conditions, the orientation sensor would output a None-Type value which cannot be used to perform calculations. To counter this issue, a rolling average function was developed to return the average angle of the last two seconds and used as the angle value to compensate.

Health and Safety Considerations

In designing RehabiliMate, a medical device, which aids in rehabilitation for individuals with loss of hand mobility due to conditions such as Multiple Sclerosis, various health and safety factors played a critical role. Throughout the design process and fabrication, prioritization was given to usability and mitigating risks associated with use. First, for accessibility/ease of use, a glove design was implemented to facilitate easy removal of the glove and donning of the device, eliminating the need to individually put on each finger component. Additionally, elastic cloth material was used for the underside of our finger components for comfort and a double hinge mechanism was incorporated to allow organic movement. Secondly, safety measures within the device's code were implemented to prevent over-stretching and strain of the hand. This was achieved through the integration of an orientation sensor that continuously monitors the range of motion. These design standards regarding ergonomics and safety align with ISO standard 9241 and ISO standard 14971 respectively. ISO standard 9421 emphasizes human-centered design principles for interactive systems to ensure user satisfaction [5]. ISO standard 14971 highlights managing risks associated with medical devices ensuring safety in clinical use [6].

For further development and approval, considerations include meeting medical electrical equipment safety requirements outlined in ISO standard 60601 and addressing biocompatibility requirements specified in ISO standard 10993. To meet standard 60601, implementing proper insulation to prevent electrical shocks as well as creating a housing box for all electrical components safely with minimal wires exposed would be vital for preventing electrical hazards [7]. RehabiliMate should only be used in a dry space away from any water sources, this reduces the need to implement any waterproof materials for

electrical safety. For ISO standard 10993, the priority for biocompatibility would be any components that come in contact with the user's body, in this case, the gloves. Biological safety tests and research must be conducted to assess cytotoxicity, sensitization, and irritation testing [8]. This material must also be comfortable and have some elasticity for user-friendliness. Based on these results, materials that pose minimal risk to users would be selected. Some glove materials for testing may include silicone, latex-free elastomers, or fabrics with antimicrobial coatings such as polyurethane coatings [9].

Summary of Contributions

Name	*MacID*	*Role*	*Contributions*
Deepam Patel	pated223	Manager	As manager, Deepam led TA meeting discussions during design studio and made sure any collective uncertainties were cleared up by contacting instructors. He created meeting agendas prior to all team meetings and submitted the preliminary Gantt Chart. He coded the data collection portion of the code, assisted with the GUI, and collaboratively worked on the "mirroring mode", and "routine training" of the design. Deepam also provided insight and ideas for the 3D CAD models, particularly for the housing of the orientation sensor, and hinges on the finger's exoskeleton. He also recorded, edited, and voiced the final prototype video. He completed the "Summary of Design Objectives", and "Appendix B: Scheduled Weekly Meetings" sections of the final design report.
Ahmed Zafar	zafara19	Subject Matter Expert	As subject matter expert, Ahmed created and organized a source database to ensure all information was easily accessible, credited, and comes from a diverse set of data.

			He developed the graphical user interface, collaborated on data collection, routine training, and mirroring functions, and intertwined the hardware of software components on the raspberry pi. Ahmed also ensured that all of the code was accessible on both a Windows Laptop and the Pi computer. Furthermore, he provided insight and ideation on the mechanism of the hinges, linear actuator application, and safety measures. He completed the "Summary of Design Process", as well as "References" and the "Comprehensive list of references"
Aizah Malik	malia48	Administrator	As administrator, Aizah submitted all project documentation on Avenue to Learn, ensuring correct file formatting and naming. She took part in the development, iterations, and assembly of the prototype. Specifically, she modelled the finger exoskeletons, bolts, linear actuator housing, and hinges along with Saanvi. She completed the "Description of Proposed Solution" and "Appendix A: Project Schedule" sections of the final design report.
Saanvi Sood	soods10	Coordinator	As administrator, Saanvi took all meeting notes during design studio directly on the agendas. She took notes for weekly TA meetings, interviews with Heather, and design review sessions. She sketched the idea for the initial prototype and cadded the elements such as finger exoskeletons, bolts, and linear actuator housing.

			She completed the “Health and Safety Considerations” and “Appendix B: Scheduled Weekly Meetings” appendix which consists of all meeting agendas with notes and logbooks for additional meetings in agenda format.

Reference List

[1] L. Kerr, V. D. Jewell, and L. Jensen, “Stretching and splinting interventions for poststroke spasticity, hand function, and functional tasks: A systematic review,” American Occupational Therapy Association, https://research.aota.org/ajot/article-abstract/74/5/7405205050p1/8419/Stretching-and-Splinting-Interventions-for (Accessed Apr. 8, 2024).

[2] R. Iodice et al., “A review of current rehabilitation practices and their benefits in patients with multiple sclerosis,” Multiple Sclerosis and Related Disorders, https://www.sciencedirect.com/science/article/abs/pii/S2211034822009646 (Accessed Apr. 8, 2024).

[3] C. A. McCallum, “Access to physical therapy services among medically underserved adults: A mixed-method study,” OUP Academic, https://academic.oup.com/ptj/article/90/5/735/2737811?login=false (Accessed Apr. 8, 2024).

[4] J. Calatayud et al., “Importance of mind-muscle connection during Progressive Resistance Training - European Journal of Applied Physiology,” SpringerLink, https://link.springer.com/article/10.1007/s00421-015-3305-7?platform=hootsuite (Accessed Apr. 8, 2024).

[5] “ISO 9241-210:2019,” ISO, https://www.iso.org/standard/77520.html (Accessed Apr. 8, 2024).

[6] “ISO 14971:2019,” ISO, https://www.iso.org/standard/72704.html (Accessed Apr. 8, 2024).

[7] “IEC 60601-2-31:2020,” ISO, https://www.iso.org/standard/72452.html (Accessed Apr. 8, 2024).

[8] “ISO 10993-17:2023,” ISO, https://www.iso.org/standard/75323.html (Accessed Apr. 8, 2024).

[9] I. Alarifi, “A comprehensive review on advancements of elastomers for engineering applications,” Advanced Industrial and Engineering Polymer Research, https://www.sciencedirect.com/science/article/pii/S2542504823000350 (Accessed Apr. 8, 2024).

Appendices

Appendix A: Project Schedule

Preliminary Gantt Chart

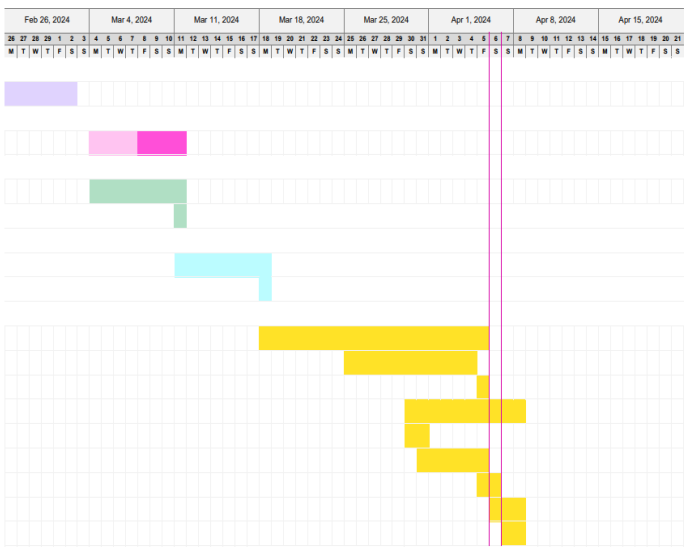
Design Project 4

IBEHS 1P10

SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

Project start: Mon, 2/26/2024
Display week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Milestone 1				
Milestone One - Stage 1,2,3 & 4	Team	100%	2/26/24	3/2/24
Milestone 2				
Milestone 2 - Stage 1,2, 3	Individual	50%	3/4/24	3/11/24
Milestone 3				
Milestone 3 - Low-Fidelity Prototype	Team	0%	3/4/24	3/11/24
Milestone 3 - Design Review	Team	0%	3/11/24	3/11/24
Milestone 4				
Revised Prototype	Team	0%	3/11/24	3/18/24
Design Review Pt.2	Team	0%	3/18/24	3/18/24
Final Submission				
Medium Fidelity Prototype	Team	0%	3/18/24	4/5/24
Presentation Slide Deck	Team	0%	3/25/24	4/4/24
Oral Presentation	Team	0%	4/5/24	4/5/24
Design Project Report	Team	0%	3/30/24	4/8/24
Report Planning	Team	0%	3/30/24	3/31/24
First Draft	Team	0%	3/31/24	4/5/24
Insert Images	Team	0%	4/5/24	4/6/24
Editing	Team	0%	4/6/24	4/8/24
Self-and-Peer Evaluation	Individual	0%	4/7/24	4/8/24



Final Gantt Chart

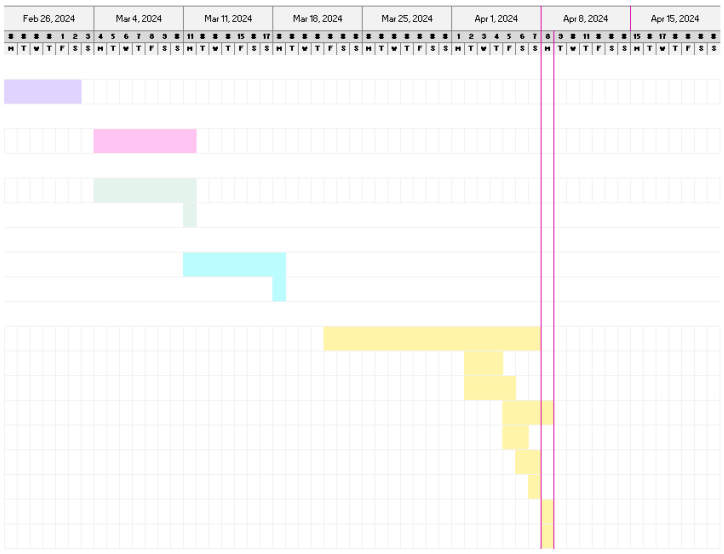
Design Project 4

IBEHS 1P10

SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

Project start: Mon, 2/26/2024
Display week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Milestone 1				
Milestone One - Stage 1,2,3 & 4	Team	100%	2/26/24	3/2/24
Milestone 2				
Milestone 2 - Stage 1,2, 3	Individual	100%	3/4/24	3/11/24
Milestone 3				
Milestone 3 - Low-Fidelity Prototype	Team	100%	3/4/24	3/11/24
Milestone 3 - Design Review	Team	100%	3/11/24	3/11/24
Milestone 4				
Revised Prototype	Team	100%	3/11/24	3/18/24
Design Review Pt.2	Team	100%	3/18/24	3/18/24
Final Submission				
Medium Fidelity Prototype	Team	100%	3/22/24	4/7/24
Presentation Slide Deck	Team	100%	4/2/24	4/4/24
Oral Presentation	Team	100%	4/2/24	4/5/24
Design Project Report	Team	100%	4/5/24	4/8/24
Report Planning	Team	100%	4/5/24	4/6/24
First Draft	Team	100%	4/6/24	4/7/24
Insert Images	Team	100%	4/7/24	4/7/24
Editing	Team	100%	4/8/24	4/8/24
Self-and-Peer Evaluation	Individual	100%	4/8/24	4/8/24



Appendix B: Scheduled Weekly Meetings

MEETING WITH TEAM 7 – Monday, MARCH. 4, 2024

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. Come up with some preliminary ideas!
2. Generate some concept sketches.
3. Complete a Pugh Matrix (probably won't happen today :/)

MEETING NOTES

1. How innovative does our design need to be?
    a. TA answer: Does not need to be completely new idea. We have a good gauge on how "out-of-box" we should be with ideas.
2. Current ideas?
    a. Main concern is her scooter, but ideas are too simple or complex. Potentially assistive device for her hand. Scooter stability device or hand breaking/arm rest device. Hand device feels more feasible.
    b. Advice from TA: Investigate MS research online. Watch avenue video on the second section of Heather's visit.
3. How much influence does Heather's opinion have?
    a. Heather is probably not coming back or individually judging groups. You must justiy with what Heather said but also a research article would be ideal.
4. Are we able to create an assistive device for her MS Fit program? Do we have to focus on things she specifically said?
    a. TA: It is valid to look at other options such as brushing teeth, getting dressed, etc.
5. Device has to medium fidelity. Scaled down, 3D printer, etc. An example: Scaled down wheelchair (didn't have to be human-sized)
6. Be ready to have a low-fidelity prototype for next week. (Think DP0: cardboard, random DS materials, not super involved)

POST-MEETING ACTION ITEMS

1. Make the low-fidelity prototype!

MEETING WITH TEAM 7 – Friday, MARCH. 8, 2024 – OUTSIDE DESIGN STUDIO

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**

Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. Low fidelity prototype building!!!!
2. Discuss ideas on how the main mechanism will actually work, just brainstorming.
3. What do we want to ask for in terms of output/input devices.

MEETING NOTES

1. Thinking about a DC motor twist mechanism
    a. Saanvi used a larger linear actuator last DP and really liked it
    b. Deepam doesn't recommend the muscle sensors
    c. Heard orientation sensors are good
2. Stuck between rehabilitation device or grabbing device
    a. Go for both?

POST-MEETING ACTION ITEMS

1. Continue brainstorming sketching for ideas pertaining to the main mechanism

MEETING WITH TEAM 7 - Monday, MARCH. 11, 2024

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. Begin thinking about how we would actually implement our solution!
2. Modify our existing low-fidelity prototype with any changes we want to make before the review.
3. Refine our current idea(s) with feedback from the TAs at the review

MEETING NOTE

1. Focus on one idea
    a. We have too many ideas going on and very little time
2. Mirroring mode proposition
    a. TAs really liked it, and suggested we go forward with it

POST-MEETING ACTION ITEMS

1. Some more preliminary concept sketches for what our solutions mechanism for pulling the fingers would actually look like.

MEETING WITH TEAM 7 – Monday, MARCH. 11, 2024 - OUTSIDE DESIGN STUDIO

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)

Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. Ideas/brainstorming on what to add to our prototype prior to the second design review.
2. Let's modify our prototype!

MEETING NOTES

1. Can now remove the idea of using force sensors, buttons, and LEDS since focus in on rehabilitation
2. Less stretchy material being used for fingers (twine) or there's a strange amount of resistance
3. Looking into ISO standards about user-interface and medical device safety

POST-MEETING ACTION ITEMS

1. Continue CADing/generating sketches for any mechanism ideas.

MEETING WITH TEAM 7 - Monday, MARCH. 18, 2024

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. Refine our prototype.
2. Discuss actual fabrication of our idea – main mechanism and coding BTS.
3. Design review – discuss what to say?
4. Incorporate feedback into our idea.
5. Calculus test today, good luck!!!!!!!!

MEETING NOTES

1. Advice on how to turn idea into reality
    a. Decision for sensor- Orientation or Force (both? -one for rehabilitation and one for grabbing)
    b. Orientation would be on gloved hand for movement and
    c. Additional glove for rehabilitation with "mirroring" technique
    d. TA advice to us is to pick one sensor and one output (she likes the rehabilitation more)
    e. Idea from team currently is leaning towards rehabilitation, if we have more time, we will do more
    f. Another team is doing gripping items
2. Ideas for CAD
    a. Ideas on google for hand prosthetics are full prosthetics that span the hand/arm
    b. We are allowed to build on top of the glove
    c. Plans to finalize what we want to CAD today

POST-MEETING ACTION ITEMS

1. Start on the CAD for both ideas and see which works.
2. Decide the final output/input devices so we can submit the form sooner rather than later

MEETING WITH TEAM 7 - Monday, MARCH. 25, 2024

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. Review any progress made since virtual meeting.
2. How are CADs going?
3. Still deciding on which sort of mechanism we want (narrowed to 2. Whichever works in testing)
4. Plans for printing and testing.
5. GRIND TIME!

MEETING NOTES

1. Focused on rehab after our last milestone
2. .ISO standard?
    a. List of standards used for medical devices (specifically for devices that go inside you)
    b. Look at physio standards
3. DP3 marks
    a. Coming out this week! All TA's just finished marking yesterday.
    b. Come to Kristin to get silly errors corrected for DP4
    c. NO personal pronouns (automatic level 2)
    d. Reference your figures in your text (as seen in figure 1... etc)
    e. Divide by section but edit it all together, make it cohesive
4. Current Design
    a. The hinge mechanism probably won't work on the thumb- it is okay
    b. In presentation justify why we didn't use thumb
    c. Have a glove!!!
5. Coding
    a. Make an interface
    b. Embed a video perhaps
    c. Flowchart is made
    d. Don't overstress what coding language you are writing in: You are allowed to code in another language

POST-MEETING ACTION ITEMS

1. This week is PRINT and TEST week
2. Book those slots!

MEETING WITH TEAM 7 - Tuesday, MARCH. 26, 2024 - OUTSIDE DESIGN STUDIO

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. Test results for both ideas?
    a. My (Deepam) idea of a fully implemented hand prosthetic had many weight flaws and it would require extreme dimensioning, something we may not have time for.
2. Let's discuss going forward with Saanvi's idea of hand exoskeleton using elastics!
3. Print an iteration?

MEETING NOTES

1. Discussed going forward with Saanvi's idea and it was agreed on.
2. Made some better sketches based off Saanvi's concept sketch with details
3. Starting to CAD parts but worried a bit about hinge movement

POST-MEETING ACTION ITEMS

1. Print Saanvi's idea and maybe assemble it next meeting.
2. Start the iteration process.

MEETING WITH TEAM 7 - Thursday, MARCH. 28, 2024 - OUTSIDE DESIGN STUDIO

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. LONG DAY TODAY, a couple Design Studio bookings
2. Printing day, find a version of the model that works.
3. Make a housing for the orientation sensor for her healthy hand
4. TESTING DAY

MEETING NOTES

1. Housing for actuator works, slides around a bit but a small piece of cardboard should help
2. Printed about 3 iterations, tried arch hinge which looks cool but its parallel with the same axis so no different affect
3. Trying double hinge out- Aizah working on that
4. GUI is coming together
5. Few problems with code planning with sensor

POST-MEETING ACTION ITEMS

1. Next time print the double hinge and test if it works
2. Goal by next DS is to have a good version of our design
3. Ask parm, or trouble shoot sensor problems

MEETING WITH TEAM 7 - Monday, APRIL 1, 2024

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. Review newest iteration of prototype (this is like our 900th prototype UGH)
2. Print more until it works.
    a. Last time only issue was that the bottom part of the finger kept coming up
    b. Could employ either a ring (we tried the Velcro it was kind of weird but could retry), or a more reinforced version of the Velcro somehow (not sure on how)
3. Coding rundown, it's been pretty chill but lets see where we're at and how much needs to be grinded out, GUI is almost done
4. Who's saying what for presentations, someone can probably start on the slides/script :/
5. Split up design report.
6. CRUNCH TIME LETS GO!

MEETING NOTES

1. Didn't end up learning HTML
    a. Good for the TA marking
2. Mirroring mechanism should work okay but haven't tried it out yet
    a. Demonstrating how our prototype works- if it takes 30 seconds then do it
3. Oral presentation rubric: getting a level 4??
    a. Any struggles over course of DP4 (technical or non-technical)
    b. -HTML but not feasible
    c. Also, can be soft skills (starting too broad, lesson learned is to take a step back, etc)
    d. STATE EXPLICITY (challenges and lessons learned)
    e. No sentences and paragraphs
4. Formability?
    a. Allowed to show design- that is not unprofessional

POST-MEETING ACTION ITEMS

1. Will need to print more due to hinge difficulties
2. Mirror mode coding.

MEETING WITH TEAM 7 - Monday, APRIL. 1, 2024 - OUTSIDE DESIGN STUDIO

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. Just did some printing with our in-class hours. Now we have a DS slot.
2. Continue printing and trying to find an iteration that works.
3. Let's do a final prototype print today (hopefully)
4. Orientation box needs work (almost figured out)

MEETING NOTES

1. Printed many iterations and finally got a solid print idea
    a. Concern with print- downsize bolts and hinges so less interference between fingers
    b. Will have final print and assembly done by next DS

Post-Meeting Action Items

1. Deepam and Ahmed can attempt to get some more significant progress done on the mirroring aspect of our design.
2. One of us can take home the Pi and do extensive testing to ensure everything works.

MEETING WITH TEAM 7 - Tuesday, APRIL. 2, 2024 - OUTSIDE DESIGN STUDIO

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. Assembly for the final printed prototype
2. Check if its functional by just doing motor.forward and backward
3. Finish the orientation sensors box.

MEETING NOTES

1. Assembly is coming together but it is missing the parts like a linear actuator (not sure how detailed assembly has to be since only finger parts are cadded–ask TA)
2. Had to reprint orientation box 3 times due to fix and lid but got it to work
3. The device is functional by doing motor.forward and back but sometimes crashes (don't know how big of a deal this is)

POST-MEETING ACTION ITEMS

1. The mirroring mode can use some more work, think of pseudocode to make it easier closer to the showcase.
2. Splitting up the report and ppt sections.

MEETING WITH TEAM 7 – Wednesday, APRIL. 3, 2024 - OUTSIDE DESIGN STUDIO

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. CODING GRIND!
2. GUI progress?
3. Let's figure out the mirroring.
4. Any pseudocode?
5. Major concern with how the linear actuator will coordinate with the orientation sensor.

MEETING NOTES

1. Ahmed is grinding that GUI and it is looking good, doesn't need support currently
2. Cooking up the mirroring code, testing as we go, looking pretty good
    a. Wrote out some pseudocode for it but may need to change to factor in when she holds hand still
3. Talk to parm as next potential step if linear actuator keeps acting up and crashing

POST-MEETING ACTION ITEMS

1. Using the test runs done today, use excel to create an equation allowing a full mapping of the linear actuators position relative to the orientation sensor.
2. PowerPoint still needs to be split up so that will need to be done.

MEETING WITH TEAM 7 – Thursday, APRIL. 4, 2024 - OUTSIDE DESIGN STUDIO

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. CODE had many issues last time, we figured it out and today we're coming with multiple versions of possible solutions.
2. PowerPoint grind time!
    a. Who's saying what and any transitions phrases for ppt.
3. TEST final prototype with everything, including mirroring.
4. The GUI needs final tweak's but it's basically done.

MEETING NOTES

1. Deepam doing introduction and need, ahmed explaining device, aizah doing challenges, saanvi doing justification and conclusion

2. GUI is done (mostly)!! Light and dark mode available, looks pretty good and variation of habby
3. MIRRORING WORKS!!!!!

POST-MEETING ACTION ITEMS

1. Complete PowerPoint and finish up some FINAL GUI functionalities.

MEETING WITH TEAM 7 - Friday, APRIL. 5, 2024 - OUTSIDE DESIGN STUDIO

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Deepam Patel**	**pated223**	**Y**
Administrator	**Aizah Malik**	**malia48**	**Y**
Coordinator	**Saanvi Sood**	**soods10**	**Y**
Subject Matter Expert	**Ahmed Zafar**	**zafara19**	**Y**
Guest			

AGENDA ITEMS

1. PRACTICE for ppt presentation.
2. Videos for Linkedin!!!
3. WOOOOHOOOO LAST DAY!

MEETING NOTES

1. Practiced presentation for like 4 hours
2. Had some trouble with slide-to-speech flow so resubmitted pretty late-talk to marking TA about that
3. Feeling ready to take on presentation! Confidence is high :)

POST-MEETING ACTION ITEMS

1. KILL THIS PRESENTATION!!!!
2. Sleep.

Appendix C: Comprehensive List of Sources:

Report Sources:

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[4] “ISO 14971:2019,” ISO, https://www.iso.org/standard/72704.html (Accessed Apr. 8, 2024).

[5] “ISO 9241-210:2019,” ISO, https://www.iso.org/standard/77520.html (Accessed Apr. 8, 2024).

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[9] L. Kerr, V. D. Jewell, and L. Jensen, “Stretching and splinting interventions for poststroke spasticity, hand function, and functional tasks: A systematic review,” American Occupational Therapy Association, https://research.aota.org/ajot/article-abstract/74/5/7405205050p1/8419/Stretching-and-Splinting-Interventions-for (Accessed Apr. 8, 2024).

Slideshow sources:

[1] R. Gatti, A. Tettamanti, S. Lambiase, P. Rossi, and M. Comola, “Improving Hand Functional Use in Subjects with Multiple Sclerosis Using a Musical Keyboard: A

Randomized Controlled Trial," Physiotherapy Research International, vol. 20, no. 2, pp. 100–107, Jun. 2015. Accessed: April 04, 2024. [Online], doi: 10.1002/pri.1600.

[2] The International Organization for Standardization, ISO 9241-304:2008 Ergonomics of human-system interaction. 2008. Accessed: Apr. 05, 2024. [Online]. Available: ISO 9241-304:2008 Ergonomics of human-system interaction

[3] The International Organization for Standardization, ISO 14971:2019 Medical Devices Application of Risk Management to Medical Devices. 2019. Accessed: Apr. 05, 2024. [Online]. Available: https://www.iso.org/standard/72704.html

Supplementary Sources:

[1] Post Stroke, "Improve Hand Spasticity After Stroke with a Daily Stretching Routine," *YouTube*. Mar. 25, 2022. [Online]. Available: https://www.youtube.com/watch?v=KrtMbqY7JmA (Accessed Mar. 4, 2024)

[2] R. Cericola, "The best smart assistive devices for people with disabilities," *Wirecutter: Reviews for the Real World*, Apr. 09, 2024. https://www.nytimes.com/wirecutter/reviews/best-assistive-smart-home-technology-for-disabled/ (Accessed Mar. 4, 2024)

[3] J. Eng *et al.*, *GRASP Graded Repetitive Arm Supplementary Program Instructor's Manual for Hospital GRASP and Home GRASP Version 2*. 2014. [Online]. Available: https://neurorehab.med.ubc.ca/files/2016/08/GRASP-Instructor-Manual-Ver2.pdf (Accessed Mar 11, 2024)

[4] K. D. Butz, G. A. Merrell, and E. A. Nauman, "A biomechanical analysis of finger joint forces and stresses developed during common daily activities," *Computer Methods in Biomechanics and Biomedical Engineering*, vol. 15, no. 2, pp. 131–140, Feb. 2012, doi: 10.1080/10255842.2010.517525. (Accessed Mar 14, 2024)

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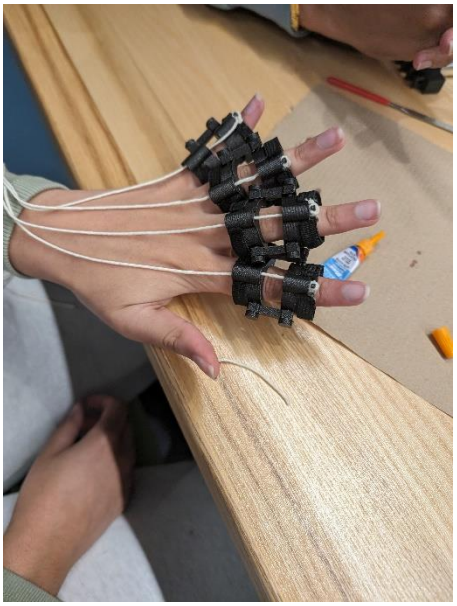
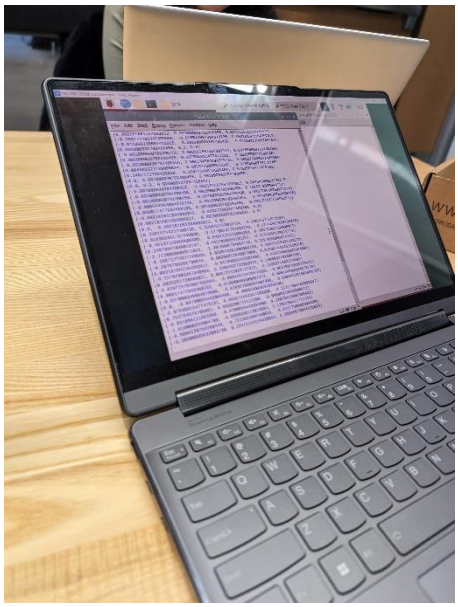
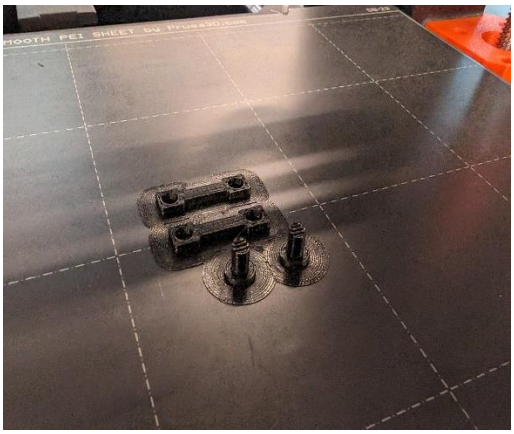
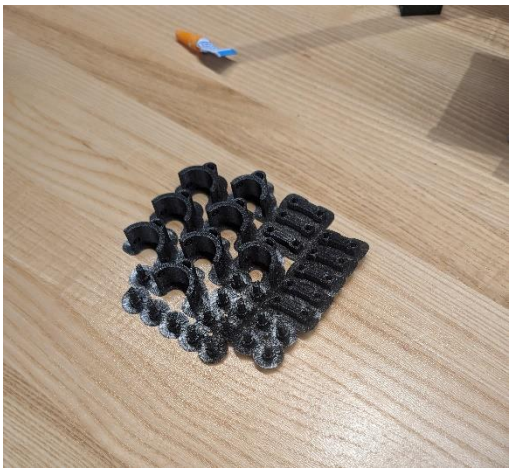
[10] "Physical Therapist Statistics: Market Report & data • GitNux," *GITNUX*, Dec. 20, 2023. https://gitnux.org/physical-therapist-statistics/ (Accessed Apr 1, 2024)

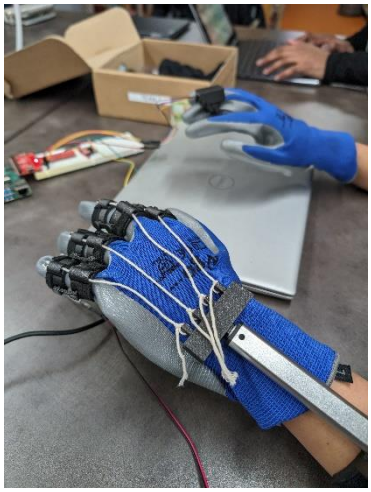
Appendix D: Additional Documentation











Appendix E: Design Studio Worksheets