BME Design-Fall 2021 - EMMALINA GROVES
Complete Notebook

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Dec 15, 2021 @02:28 PM CST

Table of Contents

Team contact Information

EMMALINA GROVES - Dec 12, 2021, 5:21 PM CST

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Abstract

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 11:09 AM CST

Course Number:

BME 400

Project Name:

Prosthetic Hand

Short Name:

Pro Hand

Abstract:

A low income, uninsured individual suffered from a severe infection in their dominant hand, which resulted in the amputation of the thumb, pointer finger, middle finger, and the medial side of the palm. The ring finger lost all of its function, and the pinky finger has only 10 degrees of flexion. The individual can not complete simple tasks such as picking up or holding everyday items. The individual lacks dexterity and strength in their dominant hand, which has caused difficulty in finding a job. Prosthetic devices that are currently on the market are too expensive for this individual to buy. In response to this problem, a low-cost, operational prosthetic controlled by wrist flexion was designed, developed, and built. It works to oppose the currently functioning pinky finger to increase hand function for this individual. The prosthetic has proven success in picking up and holding small objects such as holding a phone. Creating a low-cost, functional prosthetic device was a challenge. Various design approaches were considered and evaluated before choosing a bionic prosthetic thumb option. This option was best suited for the specifications the patient requested.

Project description

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 11:10 AM CST

Course Number:

BME 400

Project Name:

Prosthetic Hand

Short Name:

Pro Hand

Project description/problem statement:

The patient is a low-income individual who has suffered a severe infection, resulting in the loss of his thumb, index finger, and middle finger, the medial part of his palm in his dominant hand. The ring finger is immobile, while the pinky can bend up to an angle of 10 degrees. His wrist can bend 20 to 30 degrees from the neutral position. The skin spanning from his palm to ⅔ way up his forearm received an allograft. Superficial nerve function in this area is lost, resulting in hypoesthesia. There is sensitivity and pain at the locations of the lost digits, so contact should be avoided at these points. The patient is unable to complete simple tasks that require substantial weight bearing or dexterity, resulting in an inability to perform required tasks at a job or even daily living. To help the patient, a functional, long-term thumb prosthetic is designed, allowing a counter force for the pinky of up to 17N [2]. It must also provide a way to hold smaller items, such as a writing utensil, and assist in writing among other fine motor functions.

About the client:

The patient had an amputation of necrotic thumb, index, and middle fingers, and a portion of the palm resulting from a severe infection. Twelve surgeries were needed to preserve what is left at the hand. The ring finger is non-functional and acts only as an appendage. The pinky finger has approximately ten degrees of flexion at the metacarpophalangeal joint and is able to hold 2.5 kg. This number was found by the patient's occupational therapist loading the patient's pinky finger to its max force. The prosthetic works in opposition to the pinky, so it would not be beneficial if the thumb applied more force than the pinky can hold. The patient has a range of motion at the wrist limited to 10-15° of flexion and 10-15° of extension. The patient experiences pain at the location where the index and middle fingers were removed. A skin graft extends proximally from the palm to two-thirds of the way up the forearm (see: Figure). The patient has lost most superficial sensation on the areas covered by graft.

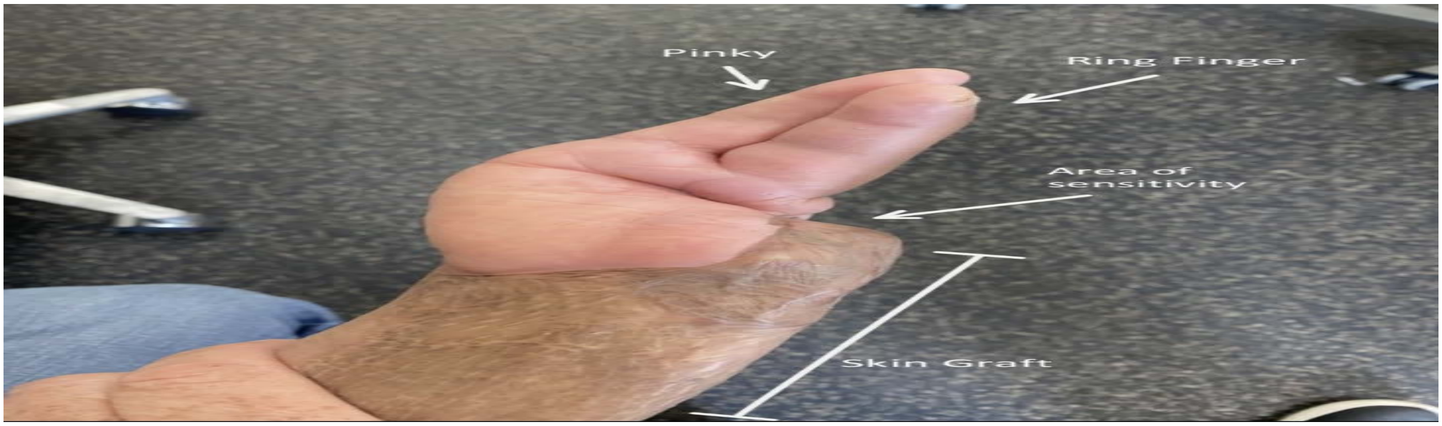

Image Caption

Figure X: Supine view of the patient's dominant (right) hand.

All files

STEPHANIE SILIN - Oct 20, 2021, 2:38 PM CDT

P_Thumb_Image1.jpg(111.9 KB) - download

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STEPHANIE SILIN - Oct 20, 2021, 2:38 PM CDT

scanhand.stl(3.5 MB) - download

2021/09/14-Initial Client Meeting

EMMALINA GROVES - Sep 15, 2021, 2:53 PM CDT

Title: Initial Client Meeting

Date: 9/14/21

Content by: Emmalina Groves

Present: Team, Client

Goals: Ask initial Questions to client to learn more about the project and what the goals of the project are

Content:

Client Questions List: (including annotations by Danielle Lefko)

General

- Can you give us a brief overview of this project and what goals and/or expectations you have for us?
  - No thumb, index finger, middle finger, ring finger is immobile and has no sensation, pinky has 10 degrees of flexion at knuckle
  - Enable the future company responded to post
    - Movable robotic based on wrist movement
    - Have an impression and 3D scan of his hand mold
  - Patient likes the cosmetic option
    - Doesn't care if it's functional
  - Thermoplastic clamping material for writing device
  - Client is open to any options
  - Goal is to stabilize and hold an object
- What are the current solutions and limitations of those? Is this a replacement? Or only used for specific settings?
- What improvements from the current methods do you hope to see in a device of this kind?

Design Specifications

- Shelf life? Is this device something that the patient could potentially grow out of? Should we plan to make this adjustable for different wearers?
- Are we modifying a current design or starting from scratch?
  - Would we have access to a current design to work with?
  - What kind of resources are available to the team (materials, people, information)?
  - Do you have any examples of how the old product worked or how you would like the new design to function differently?
- What current materials are being used to manufacture similar items? Are these materials we should attempt to use?
- Setting/operating environment this will be used in? Is this for all day use?
- Restrictions - size/weight/materials used/aesthetics?
- Standards/Specifications? Are there any specific safety hazards to avoid?
- Medical restrictions?

Methods for Testing

- If a prototype is made, do you have any suggestions for ways to test the product?
  - Should we anticipate testing the product with the patient after a prototype is made?

<u>Cost</u>

- Target product cost?
- Is there a budget for this project?

<u>Logistics</u>

- How often would you like to meet?
    - What time would work regularly?
    - How would you like to meet?

Follow up Questions:

- Budget/Funding?
- Are there any considerations for
-

  In Meeting notes:
- Patient: In chicago area
    - Had an infection and lost all digits except pinky and ring finger
        - ring finger has no sensation or function
        - pinky has about 10 degrees of flexion at large knuckle joint
    2. Patient has some wrist function in the form of flexion

Current solution being used:

1. client created splint with thermoplastic splinting material
2. splint opposes small finger and allows patient to grasp light objects in hand
3. created a splint that can hold writing utensil

Other Help:

1. Client in contact with group "enable the future"
    1. create 3D hands using leftover wrist flexion to control grab motion
    2. company working with local highschool robotics program
    3. took a mold of the patients hand- turned into online 3D file of hand mold

Goals:

1. Increase hand functionality
2. Create aesthetic prosthetic

Conclusions/action items:

10/6/2021 - Meeting with the Patient

DANIELLE LEFKO - Oct 06, 2021, 11:13 AM CDT

Title: Meeting with the Patient

Date: 10/6/2021

Content by: Danielle

Present: Danielle, Emmalina, Stephanie, Client, Patient

Goals: To learn more about what the patient wants and his limitations

Content:

Questions:

Movement

- When did your injury/infection take place?
  - March 30, 2019 (or 2018?) was the cut on finger
  - April 29 and May 1 was surgery
  - 12 surgeries on hand
  - Is your hand fully healed?
    - Yes, no more doctor for hand
- Can you demonstrate moving your wrist and fingers?
  - Pinky moves about 8-10 degrees
  - About 20 degrees at the wrist
- What is your sensation like in your fingers?
  - Are you able to put pressure on either finger without pain?
- Are there any areas on your wrist or hand that are sensitive or painful?
  - Where the ring finger connects to the hand, where other fingers would have attached
    - The web space between where the next finger would be
- Do you know the effect your injury had on your forearm muscles?
  - Skin grafting up to 2/3 on his forearm
  - Unknown how deep or how much muscles were affected
  - When wrist is flexed he is able to take resistance in both directions
  - No/slim feeling on the skin grafts
    - Could feel a pinch

Prosthetic

- What are your biggest concerns that you would like the prosthetic to help with?
  - What are some specific tasks you would want this device to help you with?
    - Wants something to be more functional for grabbing things and writing

        - Carry a little more weight to hold something stronger
            - 2-3 lbs possibly
        - Something to write better
        - Client wants him to be able to grab things to be able to go back to work
- What cosmetic features are a must for you?
- What are some of the biggest issues you have faced with past prosthetics?
    - Do you have specific improvements you would like to see with this prosthetic?
        - Wants to be able to grasp more objects
    - Have you had any issues with the weight of past prosthetics?
    - Have past prosthetics caused you discomfort? Where?
- Do you have any material allergies?
    - No allergens or irritants

- He is able to have a 4 lb weight balance on his fingers
    - 3-4lbs of force would be great

Conclusions/action items:

The team is thinking that a single motorized thumb would be ideal for the patient to avoid his sensitive areas and achieve greater grasping strength.

9/15/2021 - First Advisor Meeting

DANIELLE LEFKO - Sep 16, 2021, 7:35 PM CDT

Title: First Advisor Meeting

Date: 9/15/2021

Content by: Danielle Lefko

Present: All members

Goals: to discuss first steps

Content:

- First step is to obtain information for the PDS
- discussed meeting with client and information we got from her
    - talked about patient's needs
- important to dig deeper in info from client
    - **why is finger rigid? - find out for next meeting**
    - which hand is affected?
        - is it dominant?
    - ask client if we can interview with her client (patient)
        - get a written agreement saying we will follow HIPPA guidelines
    - ask client about budget she has
        - worse case scenario go with internal funding through BME Design
- think about some probing questions
    - determine functionality and how the prosthesis can be attached
        - velcro?
        - magnets?
    - for winter, how are gloves used?
    - how would the prosthesis interact with a phone?
        - is it good enough to just hold the phone securely?
            - what about when wearing a glove?
        - or could it be used to interact with the phone if the affected hand is dominant?
            - add a sensor for touch screen
    - could we make it so it can hold a pen?
        - depending on the functional route we choose could we add a specific holder for something like a pen?
    - what environment will the prosthetic be used in
        - this could affect materials used
        - material needs to be hard enough but also soft enough for the desired tasks

Conclusions/action items:

- answer the first two fingers of the hand metaphor
    - identifying problem and characterizing the problem
- Find out why is the ring finger ridged?
- complete pds
- look up cosmesis -> not looking like having a disability
- put client description in own words
    - approach from engineering perspective

- don't solve problem until next week - this week is about defining and characterizing the problem

9/22/2021 - Advisor Meeting

DANIELLE LEFKO - Sep 22, 2021, 5:40 PM CDT

Title: Advisor Meeting

Date: 9/22/2021

Content by: Danielle Lefko

Present: all members

Goals: to discuss our current position in the project

Content:

- what's the problem and why is it a problem = opening narrative for PDS
- clients description is background
- what does the patient do regularly
    - what environment will the device need to function under?
        - normal human environment or extreme settings for work?
- what is the availability of access to the patient?
    - meeting over zoom initially through a translator
- what is the nature of the injury?
- what is the nature of the residual limb?
- where are we starting from? what do we have to work with?
- try to not invent anything wherever possible
    - use parts of other people's invention
- grant proposal will be needed
    - explain why money is needed and expected outcome
- key grip - pointer and middle finger with thumb
    - how can we control this?
- design ideas need to be testable with the constraints we have
    - need details with the function of his hand/arm
        - 10 degrees of flexion?
            - what caused the limited range of function? will it improve over time?
- use a cam system to amplify force
    - fiskars

Conclusions/action items:

need to set up an interview with the patient to get a better understanding of the situation

write a grant proposal for after first presentation (before Oct 15)

9/29/21 Advisor Meeting

KAREN SCHARLAU (kscharlau@wisc.edu) - Sep 29, 2021, 5:24 PM CDT

Title: Advisor Meeting

Date: 9/29/20

Content by: Karen Scharlau

Present: Danielle, Emily, Stephanie, Karen and Mitchell Tyler

Goals: Get Mitch caught up on our project and make a plan for the next week.

Content:

- Presentation moved back a week
- Continue working on the funding proposal
    - Let Mitch know if we need money before then for prototyping
- Continue to generate design features
- Cement our design more before submitting funding proposal
- Send draft of funding proposal to Mitch before Wednesday next week
- PDS review
-

Conclusions/action items:

Send Mitch a draft of the funding proposal before next Wednesday.

Send updated PDS to Mitch before next Wednesday.

10/20/21 Advisor Meeting

KAREN SCHARLAU (kscharlau@wisc.edu) - Oct 20, 2021, 5:10 PM CDT

Title: Advisor Meeting

Date: 10/20/21

Content by: Karen Scharlau

Present: Team and Mitchell Tyler

Goals: To get feedback on the presentation and project.

Content:

Feedback on presentation:

- Put problem statement first

- Put load testing in future work

- Future work was too vague

- No good timeline

-Need more CAD models

- Less "Um's", pause instead

Concerns:

-Chose the most complicated design

-Need actuator and linear motor for bionic design.

-Should probably simplify the design

-Make sure it's feasible

Conclusions/action items:

Team should critique our design decision to decide if we can really do it. Come up with a justification, and complete the funding proposal.

Evolve PDS and revise specifications.

10/27/21 Advisor Meeting

KAREN SCHARLAU (kscharlau@wisc.edu) - Oct 27, 2021, 4:56 PM CDT

Title: Advisor Meeting

Date: 10/27/21

Content by: Karen Scharlau

Present: Team + Mitch

Goals: To update Mitch on the new designs and progress the team has made.

Content:

- Decided to use flex sensor

-Attachment of flex sensor to hand/forearm: Cuff design

-New thumb design has 2 joints and one actuator

- Money : Budget Proposal sent to Mitch

Conclusions/action items:

-Complete design by figuring out how to attach flex sensor and share with Mitch at next meeting

-Order smaller/cheaper materials

-Review budget proposal when Mitch gets it back to the team

-Don't make any large purchases without prior approval

11/3/21 Advisor Meeting

KAREN SCHARLAU (kscharlau@wisc.edu) - Nov 03, 2021, 5:11 PM CDT

Title: 11/3/21 Advisor Meeting

Date: 11/3/21

Content by: Karen Scharlau

Present: Karen, Emily, Stephanie, Mitch

Goals: To update Mitch on the team activities and progress.

Content:

- Team now has a $500 budget

- Need to order through specific websites

- Have a makerspace account named: BME_ProThumb

- Preliminary Report comments - need to change the narrative

- If it worked, why? If not, why?

-For show and tell: What is the problem, why is it a problem, what are you doing to solve the problem?

- If the vendors don't have our materials, we need to make a justification

-Emily shared her solidworks design:)

-Nylon 66 or 67 was suggested by Mitch for our pins to reduce friction

-Interference fit on the outside of pins and a clearance fit on the inside

-Voltage splitter to power both the arduino and the motor

-Look for arduino attachments that may do that for us

Conclusions/action items:

-Find products on approved websites

-If not, create a justification and send to Mitch

-Next week come up with a framework of testing protocol and deliver next week (How well it moves, is it repeatable)

11/10/21 Advisor Meeting

KAREN SCHARLAU (kscharlau@wisc.edu) - Nov 10, 2021, 5:00 PM CST

Title: Advisor Meeting

Date: 11/10/21

Content by: Karen Scharlau

Present: Danielle, Emily, Karen, Stephanie, Mitch

Goals: To update Mitch on team activities.

Content:

- Budget justification
  - Send to Mitch
  - Could not find most of our products through shopUW
- Notebook comments
  - Grades are not being put on canvas - don't worry
  - Very robust poster presentation, final report, final notebook
  - Start working on the report and ask mitch any questions
  - The project needs to be able to be replicated directly from the notebook
  - Add tons more detail to the notebook and create more of a narrative
  - What we did, why we did it, how we did it. The notebook demonstrates who contributed what to the project
  - Add names to contact list in notebook
  - Fill in project description page
  - what, why it exists, and the approach/what you need to do
  - Figure captions - make them very thorough
  - Make conclusion/action items more clear. Elaborate why they are action items and how is it going to lead to the next point
  - STRENGTHEN notebook for a good grade
  - Add design matrix and decisions based on that into notebook
  - Justify and document everything
  - Why we made the decisions we did
- Ordered the motor and flex sensor so that the prototype can be built in time
- First rendition of the prototype was able to be printed and was functional
- Do independent testing of the mechanical, electrical, and drive system

Conclusions/action items:

Add necessary changes to the notebook so that the project is well-documented. Send the budget justification to Mitch after the meeting so that the materials needed can be ordered.

11/17/21 Advisor Meeting

KAREN SCHARLAU (kscharlau@wisc.edu) - Nov 17, 2021, 4:45 PM CST

Title: Advisor Meeting

Date: 11/17/21

Content by: Karen Scharlau

Present: Karen, Danielle, Emily, Mitchell Tyler

Goals: To update Mitch on team activities.

Content:

- Send Budget Justification to John Puccinelli

- Will have to ask about getting reimbursed for motor and flex sensor

- Makerspace as good resource - will be using thermoform for cuff

- Put forearm in solid works and print it for the presentation

- Mitch will be in person on campus December 8th

- Create/improve testing protocol

Conclusions/action items:

-Send Budget Justification to John Puccinelli ASAP

- Get forearm dimensions from the client

- Send draft of testing protocol to Mitch by next Wednesday

Motor Testing Video

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 11:25 AM CST

IMG_5632.MOV(7.7 MB) - download A video of the motor successfully working to push the mechanical thumb into a gripping position.

Design Matrix

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 11:22 AM CST

Preliminary Design Evaluation

Design Matrix

Criteria For Design Matrix:

1. **Comfort:** The user must be able to use the product for long periods of time with no feelings of physical discomfort or harm. Meeting this requirement would indicate a high-scoring design; a low score shows a design that does not enable as much comfort for the user.
2. **Ease of use:** Means that the user will have little to no trouble with device assembly, wear, sanitation, and reuse. A high score represents a design that encourages the user to have a convenient experience, and a low score proves a design's complexity when it comes to the process of use.
3. **Cost:** Cost is in reference to how much creating a prototype for this design would cost. Given our budget limitations, cost is an especially important consideration. A higher score corresponds to a lower overall cost and a low score in the matrix corresponds to a high total cost.
4. **Cosmesis:** A physical appearance that closely resembles the patient's unaffected hand and skin tone will allow the prosthetic to blend in. The patient has reinforced that this criteria is something meaningful.
5. **Functionality:** Functionality references the prosthetic's ability to perform tasks deemed necessary. A high score in functionality means the device is able to perform important daily tasks with minimal effort.
6. **Ease of Fabrication:** A measure of how realistic a design is able to be made based on the available facilities and skills of the team. A high score indicates that the design is easier to make, while a low score indicates challenges in the fabrication process.
7. **Strength:** The prosthetic must be strong enough to hold weight in the hand without deforming or moving on the forearm. Strength will also incorporate maximum grip force. A higher strength score means higher material strength and a higher maximum grip strength.
8. **Response Time:** Response time is in reference to the time it takes between the patient's decision to perform an action using the device and the action being performed. Use of electronic components may lead to slower reaction times than a fully mechanical prosthetic.

Table 1: **Design matrix demonstrating how the bionic design is chosen**

Name		Cosmetic		Mechanical		Bionic	
Criteria:	Weight:						
Comfort	20%	5/5	20	(1/5)	4	(3/5)	
Ease of use	15%	1/5	3	(3/5)	9	(5/5)	
Cost	15%	4/5	12	(4/5)	12	(1/5)	
Cosmesis	5%	5/5	5	(1/5)	1	(2/5)	
Functionality	15%	1/5	3	(2/5)	6	(5/5)	
Ease of Fabrication	10%	4/5	8	(5/5)	10	(1/5)	
Strength	15%	1/5	3	(2/5)	2	(5/5)	
Response Time	5%	1/5	1	(5/5)	5	(3/5)	
Total	100%	55		49		57	

Design Matrix Summary

Design 1: Cosmetic

This purely cosmetic design would be made with materials that best resemble the touch and feel of skin, however would not provide much additional functionality past a backbone for the patient to pinch against with his pinky finger. This design would be easier to fabricate as it would have less moving pieces, but creating a realistic looking finger could be challenging. Additionally without any moving pieces this design would have less potential pinch points, or electrical issues making it comfortable and more easily worn in the rain/water. However, this design does provide much functionality or strength to the patient as some of the other designs and therefore it was not selected.

Design 2: Mechanical

The fully mechanical design is the most simple design. The string is shortened by flexion of the wrist, allowing the user to grasp items. The major shortcoming in this design with regards to the patient, is that they are unable to move their wrist more than 20-30 degrees. This would severely limit either the range of motion of the thumb or grip strength of the prosthetic, as with increased range of motion the force provided would decrease. It is a straight forward design, so it scored well in the ease of use, cost, and ease of fabrication. One of the major benefits of this design is the low cost. However, since the client did not provide a budget, it is crucial to keep the cost relatively low so that it can be funded from outside sources. The response time in the mechanical design would also be the best because there will be no lag time that some of the electronic components in other designs may have.

Design 3: Bionic

The bionic design meets some of the client's most important requirements, which are strength and functionality. These criteria would allow the patient to go back to work. The design would be far more complex and therefore expensive than the other designs. However, based on the criteria of making an inexpensive model, this is a trade-off for making a prosthetic that works for the user. There would also be a larger learning curve for the user, resulting in a lower score in the ease-of-use category. Finally, when considering the difficulty of designing a base mechanical support, the electronics required, and the timeframe available, it was concluded that the bionic design is too difficult to fabricate in the given amount of time, resulting in a low ease of fabrication score. However, it came to light that the patient experiences sensitivity and pain during palpation of the amputation site. Due to this, the prosthetic design was limited to the thumb, and thus the decision was reversed and the bionic model became feasible.

Proposed Final Design

The overall winner of the design matrix was the bionic design. This design won because it scored the highest in the most valued categories. The bionic design provides the user with the greatest amount of force and strength when grasping and holding objects. This was the most important quality to consider for the patient because he is looking for a solution to help him get back into the workforce. In addition to strength, the bionic design is also easier to use for the patient because of the limited flexion in his wrist. The use of a microcontroller allows for the patient to be able to grasp many objects of different sizes and weights. The microcontroller is able to amplify any signal read from the forearm into any movement response necessary. This is valuable to the patient because he will be able to hold larger and heavier objects as well as utilize smaller movements for tasks such as writing. This solution will take some adjustment initially, but it will ultimately be a better solution for the patient.

Final Design

Myoelectric electrodes were attached to the left forearm of a test subject and hooked up to an electrical circuit in order to read the signals. Clear signals could not be obtained from myoelectric sensors. For this reason, the myoelectric sensor was replaced with a flex sensor for the final design. This was chosen because it is a simpler mechanism that will give clear changes in resistances based on flexion. The flex sensor will be placed on the wrist to sense wrist flexion, which will control the degree of flexion of the thumb. The flex sensor was also a better option because the myoelectric electrodes were not reusable.

Material Documentation

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 11:51 AM CST

Title: Material Expenses Documentation

Date: 10/20/2021

Content by: Stephanie Silin and Karen Scharlau

Present: N/A

Goals: To document project costs.

Content:

Table 2: Summary of project costs.

Item	Manufacturer	Quantity	Price	Total
Glue	Buy On Purpose	1	$10.13	$10.13
Velcro Ties	Buy On Purpose	1	$5.79	$5.79
Clevis pins	Grainger	10	$1.66	$16.60
Arduino Nano Every	Arduino	1	$12.90	$12.90
9 V Rechargeable Batteries	EBL	1	$26.99	$26.99
Arm Sleeve	IovyoCoCo	1	$13.24	$13.24
Flex Seal	Flex Seal	1	$14.99	$14.99
Motor Driver	HiLetgo	1	$10.99	$10.99
3D Printing	N/A	N/A	N/A	$20.00
Flex Sensor	Adafruit	1	$12.00	$12.00
Polystyrene	Makerspace	2	$15.00	$30.00
			Total:	$173.63

The project was able to stay under $200.

Conclusions/action items:

12/1/21 Fabrication- Grip Test

EMMALINA GROVES - Dec 12, 2021, 6:35 PM CST

Title: Flex Seal Grip Test on Printed Hand

Date: 12/1/21

Content by: Emmalina Groves

Present: Danielle, Stephanie, Ren

Goals: Apply flex seal to printed fingers to see if it provides helpful gripping capability. Use as first test to see what dried flex seal feels like.

Content:

Images of dipping 3D printed hand model in flex seal. Flex seal dried overnight and was inspected the next day. Team determined that flex seal was appropriate in improving grip strength for the tip of our mechanical thumb.

Conclusions/action items:

Use flex seal and dip our machanical prototype thumb tip. Team decided we will dip the thumb tip in flex seal and use a fabric to add texture during the drying process. We will add the flex seal coat to the top of our 3D printed final design.

12/2/21 Cuff Mold

EMMALINA GROVES - Dec 12, 2021, 7:06 PM CST

Title: Cuff Mold Modeling

Date: 12/2/21

Content by: Emmalina Groves

Present: Danielle, Staphanie, Ren

Goals: Use wood and clay to mold a forearm model to use for thermoforming the forearm cuff.

Content:

Need to use the dimensions given by Ms. Katz to create a forearm model.

Figure: Forearm model made of clay and wooden rod. Circumference measurements exact to patient's forearm

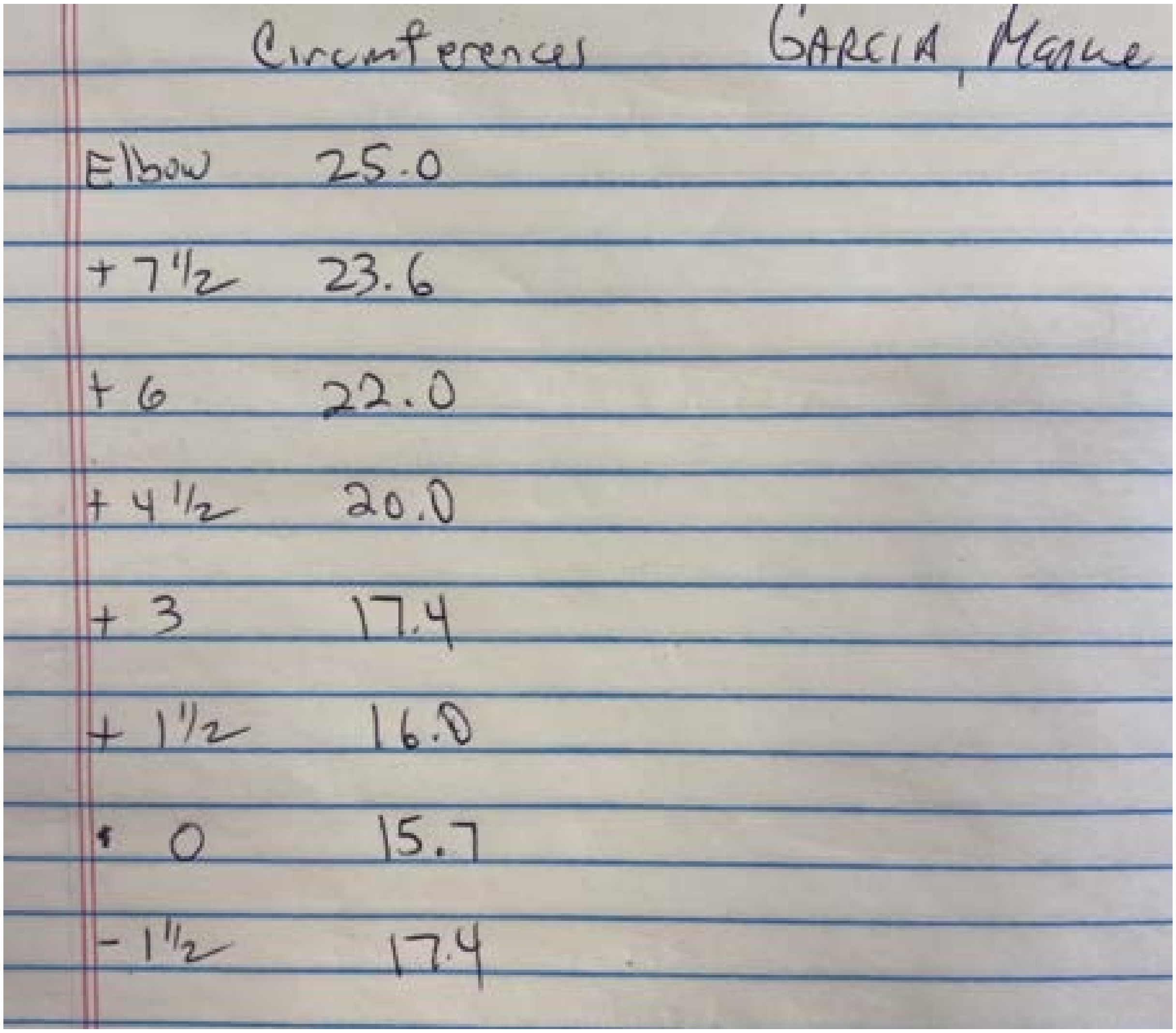


Figure: Measure of circumferences and distances on forearm

Conclusions/action items:

Use modeled forearm to thermoform a cuff. This cuff we be how the mechanical thumb will attach well to the linear actuator and other electronic parts. Thermofoam machine located in makerspace.

12/3/21 Thermoforming the Cuff

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 11:52 AM (

Title: Thermoforming the cuff

Date: 12/3/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To form the plastic to the mold in order to create the cuff.

Content:

I bought two sheets of 1/8" polystyrene from the makerspace after setting up the thermoformer to start warming up. Once the machine was warmed up, I se the mold of the forearm into the machine so that the "top" of the forearm would get molded. Then the plastic was loaded in, and I waited a couple minutes fo to heat up. It started to droop in various places, which told me and the makerspace worker that it was ready. I pulled the lever that pushes the mold into the plastic, then pushed the vacuum button. I waited for the plastic to pull around the mold, then stopped the vacuum function. I waited for it to cool, then pulled out the mold. The heat of the plastic melted the clay a little bit, so I went and remolded the forearm mold. I measured to make sure it was the same as befor then brought it back and repeated the same thing on the other side so that I had two sheet of molded plastic. Stephanie and Danielle showed up and helpe cut out and sand the molds I made. Then, after looking at the sizing of the cuffs, I sanded off more material from the cuffs.

While I was waiting for the thermoformer machine to heat up, I sewed a sweatshirt sleeve that I found from the scrap bin of the makerspace into a sleeve th could house the flex sensor and fit underneath the forearm cuff.

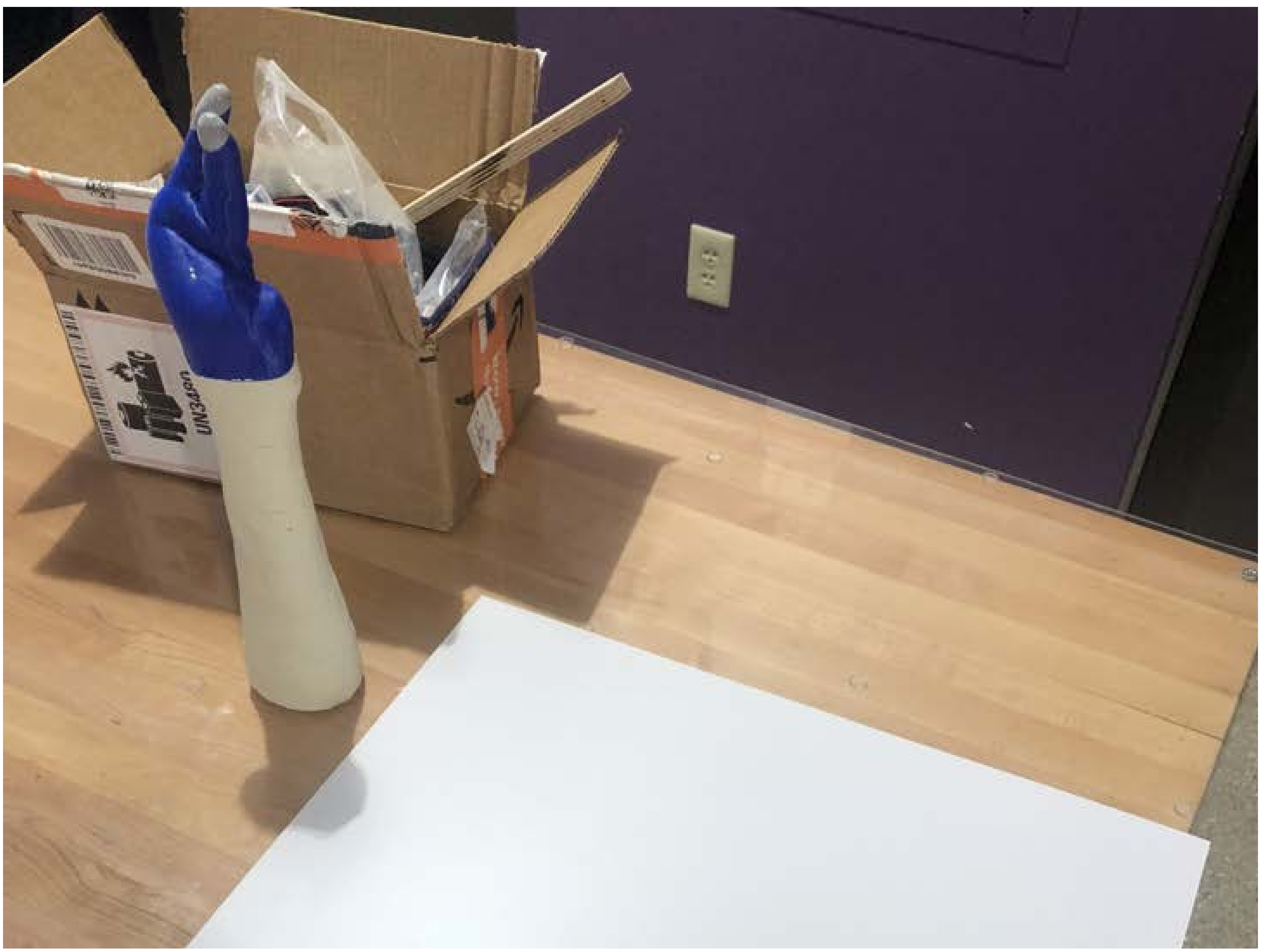


Figure X: The forearm mold pictured next to the sheet of polystyrene plastic used to mold the cuff.

Figure X: A picture of the sleeve that I sewed that will be placed underneath the forearm cuff.

Figure X: The polystyrene plastic after being molded in the thermoformer, but before being cut.

Figure X: The two cuff pieces after initially being cut out.

Conclusions/action items:

The cuff pieces are sturdy and look great. I am happy with how they turned out. I will velcro the cuffs together later to show that they fit together.

12/7/21 Testing Protocol

EMMALINA GROVES - Dec 12, 2021, 7:34 PM CST

Title: Testing Protocol for Prototype

Date: 12/7/21

Content by: Emmalina Groves

Present: Danielle Lefko

Goals: Define a testing protocol that quantifies the capabilities of the prototype, and highlights the areas where improvment is needed.

Content:

Testing Protocol for Prototype

The prototype will be tested with the objective of characterizing the functionality of the design. Standards will be set prior to performing the desired tests, and testing results will be compared to the previously agreed upon standards. To fully characterize the prototype, a basic test of motion will be performed(n = 10). This test will be a pass/fail test and determine if replicated movement is possible. If passed, the next tests will be Range of Motion and Reaction time testing. These tests will utilize the same testing method as the initial function test, but measurement aspects will be added.

Key Qs to answer:

- Does it work?
- How does it work?
- What can it do?
- How can we measure it?

Testing Ideas:

1. Does it work test: Test the capabilities of the device by deploying the system
    1. Deploy the flex sensor at full flexion amount to input highest resistance
    2. Allow mechanical movement of linear actuator and prosthetic thumb to full flexion
    3. Repeat steps 1 and 2 a substantial amount of times (n>10)
    4. Note the movement of each trial and if any of the trials are abnormal
    5. Make a determination on if the device is functioning properly
2. Measure ROM on thumb by deploying the device multiple times to see if consistent ROM is achieved (performed by measuring linear motion and angle angle of motion)
    1. Measure initial angle between tip of thumb and linear direction of the cuff, this is a baseline angle measurement
    2. Deploy the flex sensor at full flexion amount to input highest resistance
    3. Allow mechanical movement of linear actuator and prosthetic thumb to full flexion
    4. Reseasure angle between linear direction of cuff and the tip of the thumb
    5. Find the difference between final and initial angle to determine range of motion

6. Repeat experiment at least n=3 times to determine accuracy of measurements
7. Find average and standard deviation of trials
8. Repeat steps 1-7 for various initial resistance values to find accuracy of device at various flexion amounts

3. Measure force exerted when thumb is actively moving
    1. Stabilize base of device so only movement is in the thumb portion
    2. Attach thumb to a crane scale at the hook using a string perpendicular to the scale (and parallel to the ground)
    3. Activate the grip of the thumb
    4. Measure the amount of force that it pulls

4. Reaction time from change in resistance of flex sensor to finished movement in the thumb, measure enough times to get an average reaction time
    1. Deploy the flex sensor at full flexion amount to input highest resistance
    2. Allow mechanical movement of linear actuator and prosthetic thumb to full flexion
    3. Use stopwatch to measure time for reaction
    4. Take average and st deviation
    5. Determine if reaction time is acceptable based on agreed upon initial acceptable value
5. Do math based on motor force to see what force distribution at tip on thumb should be, find a way to test actual values and compare to the theoretical value
    1. Look into finding theoretical force value during flexion based on linear actuator output
        1. Figure out how to do this math(statics/dynamics refresher)
    2. Compare theoretical force values to experimentally determined values in part 2
    3. Make a determination on of the output force is acceptable for the device
6. Force analysis on solidworks to potentially get a theoretical force value by inputting a force from the motor
    1. Use modelling capabilities in solidworks to determine from input force what anticipated force distribution on materials at the thumb tip would look like
    2. **Learn how to use solidworks in this capacity

Conclusions/action items:

Perform the tests defined above. Use the results of the tests to make necessary changes to the prototype and re-test as necessary. Edits to the testing protocol are likely also necessary as the prototype is completed and ways to define movement is clearer.

Device Testing

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 12:00 PM CST

Title: Device Testing

Date: 12/4/21

Content by: Karen

Present: Team

Goals: To document the tests run on the prosthetic thumb.

Content:

Testing

The device was evaluated with a series of tests, each of which analyzed various aspects of the prototype. Initially, a general test of motion was performed (n=10) to determine if prototype motion was replicable. To perform this test, the flex sensor is deployed at full flexion amount to input highest resistance. Following, the device performs mechanical movement of the linear actuator and prosthetic thumb to full flexion. The movement of each trial is noted, specifying if any abnormal movement is detected. The general motion test is evaluated on a pass fail basis, and no further testing is performed until a pass is achieved.

Second, a range of motion test is performed (n=10) on the thumb by deploying the device to full flexion repeatedly to see if a consistent range of motion is achieved. Prototype was imaged at each position for each trial and images were analyzed in ImageJ. Angles in imageJ were measured from the axis determined by the linear cuff.

Third, a force test was performed to determine the average peak force the thumb could produce at the distal ½" portion of the second phalanx of the thumb. This was done by fixing the cuff attachment to a rigid surface and attaching a crane scale to the second phalanx (see Figure 21). From here the thumb was set in motion and the peak force exerted by the thumb over the whole range of motion was recorded for a set of n = 10 trials. The aim of this trial is to determine whether the thumb could produce an adequate counter for the pinky finger of the patient. The patient's pinky finger can hold 17N, meaning the thumb needs to be able to counter that amount of force [2].

Lastly, a reaction time test was performed. The aim of this test was to determine if the time from sensor bending to full flexion of the thumb could be done in under 2.75s. This time is to account for 2.5s of flexion and 0.25s of run time on the code. This test is performed by timing the action from bending of the sensor to full flexion, and repeated for a total of 10 trials. To determine if the thumb could fully flex in that time a one-sided z-test is performed on the thumb to ensure it is within that range.

Figure 21: Example of Force Testing with a Crane Scale. The handheld force sensor was held still while the prosthetic thumb flexed.

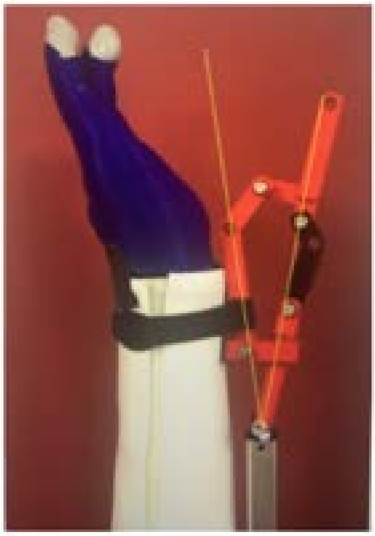


Figure 22: Example measurement of ImageJ analysis. Pictured is angle of full flexion, not example calculation. ImageJ measures an angle of 18.35 degrees.

Figure 23: The prosthetic thumb successfully holding a small container.

Force Testing

STEPHANIE SILIN - Dec 15, 2021, 2:05 PM CST

Title: Force Testing

Date: 12/6

Content by: Stephanie

Present: Stephanie

Goals: To test force production of the thumb

Content:

See Attachement for Data

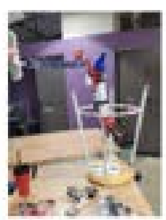
A force test was performed to determine the average peak force the thumb could produce at the distal ½" portion of the second phalanx of the thumb. This was done by fixing the cuff attachment to a rigid surface and attaching a crane scale to the second phalanx (see Figure 21). From here the thumb was set in motion and the peak force exerted by the thumb over the whole range of motion was recorded for a set of n = 10 trials. The aim of this trial is to determine whether the thumb could produce an adequate counter for the pinky finger of the patient. The patient's pinky finger can hold 17N, meaning the thumb needs to be able to counter that amount of force.

The force test produced an average maximum force of 4.45N with a variance of 0.214. This was lower than the desired 17N counter for the patient's pinky finger. The design of the thumb has a flaw in which it can flex backwards which needs to be corrected, after which more force testing will be done to determine the force is significantly above 17N.

Conclusions/action items:

This is not enough force, the thumb model needs to be reworked because it is beding backwards during testing.

STEPHANIE SILIN - Dec 15, 2021, 2:06 PM CST



Force_Test.xlsx(387.1 KB) - download

Reaction Time Testing

STEPHANIE SILIN - Dec 15, 2021, 2:08 PM CST

Title: Reaction Time Testing

Date: 12/1

Content by: All

Present: All

Goals: Test the amount of time from sensor trigger to finished motion of the thumb

Content:

See attachment for data

A reaction time test was performed. The aim of this test was to determine if the time from sensor bending to full flexion of the thumb could be done in under 2.75s. This time is to account for 2.5s of flexion and 0.25s of run time on the code. This test is performed by timing the action from bending of the sensor to full flexion, and repeated for a total of 10 trials. To determine if the thumb could fully flex in that time a one-sided z-test is performed on the thumb to ensure it is within that range.

The reaction time test produced an average of 2.44s reaction time between the sensor being bent and full flexion of the thumb. This was significantly less than 2.75s with an alpha of 0.05 given the results had a p-value of 0.0018, the value 2.75s was chosen to account for 2.5s for full flexion and 0.25s of run time for the code. Results of the reaction time test allow confidence that the full flexion mechanism can reliably deploy in less than 2.75s.

Conclusions/action items:

Maybe the motor could be replaced with a smaller quicker one? We are not even using the full extension of our current motor and this is under 2.75s but 2.5s is still kinda slow.

STEPHANIE SILIN - Dec 15, 2021, 2:08 PM CST

Timing_test.xlsx(4.9 KB) - download

ROM Testing

STEPHANIE SILIN - Dec 15, 2021, 2:11 PM CST

Title: Range of Motion Testing

Date: 12/1

Content by: All

Present: All

Goals: To test the range of motion of the thumb

Content:

See attachments

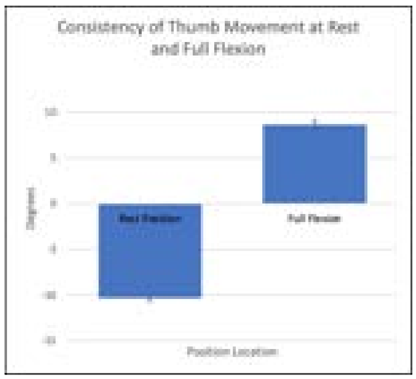


Figure: Plot of thumb motion testing displaying the relationship between the position of the thumb and angle of flexion (angle of the thumb relative to the neutral axis).

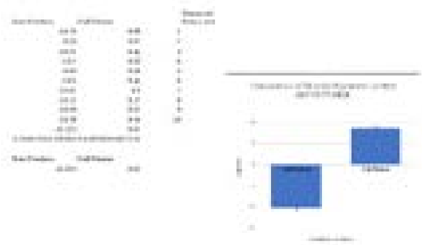
The range of motion tests produced a range of 7-13cm of motion with an average of 20 degrees of flexion. A range of motion 7-13cm signifies the variable lengths of objects that can be held by the design, with 13cm being the largest possible and 7cm being the smallest object length. As the range of motion and the degree of flexion are directly related, increasing the degrees of flexion capable of being produced by the prototype will directly increase the range of motion possible.

A range of motion test is performed (n=10) on the thumb by deploying the device to full flexion repeatedly to see if a consistent range of motion is achieved. Prototype was imaged at each position for each trial and images were analyzed in ImageJ. Angles in imageJ were measured from the axis determined by the linear cuff.

Conclusions/action items:

The thub could be made longer to allow for a larger range of motion, however if this is done then the team may need to rework the mechanics to ensure the torque is not sacrificed too much for this.

STEPHANIE SILIN - Dec 15, 2021, 2:11 PM CST



BME_400_ROM_Data.xlsx(14.7 KB) - download

Progress Report 1

STEPHANIE SILIN - Oct 20, 2021, 2:25 PM CDT

Progress_Report_1_Pro_Hand.docx(13.1 KB) - download

Progress Report 2

STEPHANIE SILIN - Oct 20, 2021, 2:26 PM CDT

Prosthetic Hand

(Pro Hand)

Problem Statement

Summary of Team Role Accomplishments

Brief Status Update

Progress_Report_2_Pro_Hand.pdf(70.9 KB) - download

Progress Report 3

STEPHANIE SILIN - Oct 20, 2021, 2:27 PM CDT


Prosthetic Hand
(Pro Hand)

Problem Statement

Summary of Team Role Accomplishments

Brief Status Update

Progress_Report_3_Pro_Hand.pdf(271.9 KB) - download

Progress Report 4

STEPHANIE SILIN - Oct 20, 2021, 2:29 PM CDT


Prosthetic Hand
(Pro Hand)

Problem Statement

Summary of Team Role Accomplishments

Brief Status Update

Progress_Report_4_Pro_Hand_1_.pdf(270.9 KB) - download

Progress Report 5

STEPHANIE SILIN - Oct 20, 2021, 2:29 PM CDT

Progress_Report_5_Pro_Hand.pdf(272.6 KB) - download

Progress Report 6

STEPHANIE SILIN - Oct 20, 2021, 2:30 PM CDT

Progress_Report_6_Pro_Hand.docx(269.7 KB) - download

Progress Report 7

EMMALINA GROVES - Dec 12, 2021, 7:40 PM CST

Progress_Report_7_Pro_Hand.docx(270 KB) - download

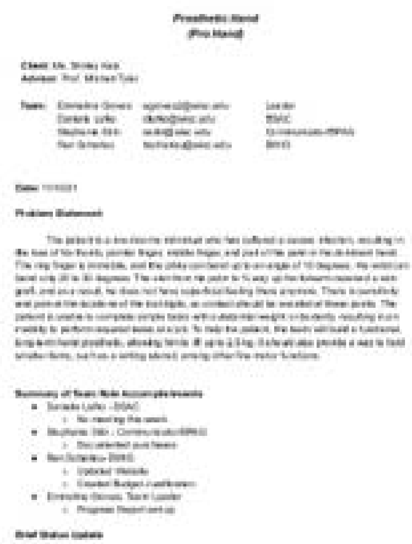
Progress Report 8

EMMALINA GROVES - Dec 12, 2021, 7:42 PM CST

Progress_Report_8_Pro_Hand.pdf(335.4 KB) - download

Progress Report 9

EMMALINA GROVES - Dec 12, 2021, 7:43 PM CST



Progress_Report_9_Pro_Hand.pdf(338 KB) - download

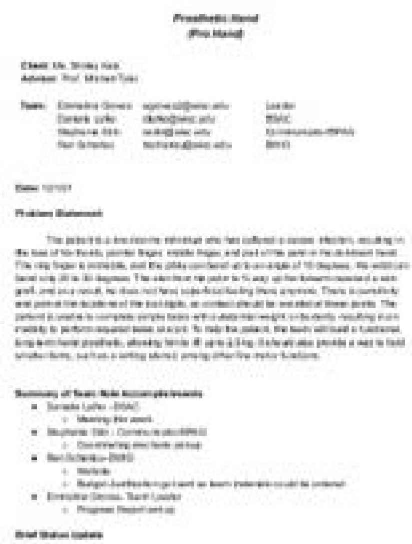
Progress Report 10

EMMALINA GROVES - Dec 12, 2021, 7:44 PM CST

Progress_Report_10_Pro_Hand.pdf(338.1 KB) - download

Progress Report 11

EMMALINA GROVES - Dec 12, 2021, 7:45 PM CST


Prosthetic Hand
(Pro Hand)

Client:

Advisor:

Team:

Date:

Problem Statement

Summary of Team Role Accomplishments

Brief Status Update

Progress_Report_11_Pro_Hand.pdf(338.1 KB) - download

Progress Report 12

EMMALINA GROVES - Dec 12, 2021, 7:46 PM CST


Prosthetic Hand
(Pro Hand)

Problem Statement

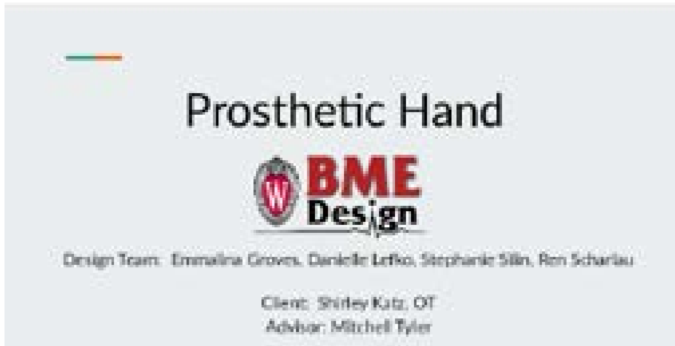
Summary of Team Role Accomplishments

Brief Status Update

Progress_Report_12_Pro_Hand.pdf(340.3 KB) - download

Preliminary Presentation

STEPHANIE SILIN - Oct 20, 2021, 2:31 PM CDT



Preliminary_Presentation_1_.pptx(12.3 MB) - download

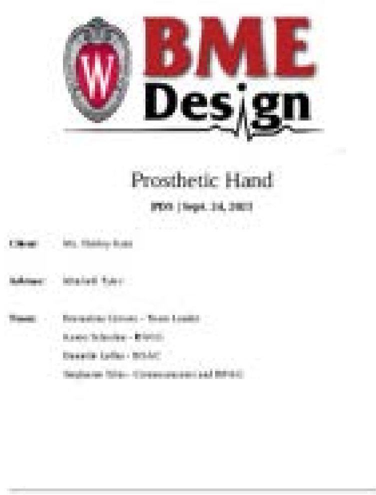
Preliminary Report

STEPHANIE SILIN - Oct 20, 2021, 2:36 PM CDT

Preliminary_Report.pdf(10.5 MB) - download

PDS

STEPHANIE SILIN - Oct 20, 2021, 2:34 PM CDT


BME Design

Prosthetic Hand

PDS.docx(122.1 KB) - download

Final Poster

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 11:55 AM CST

Screenshot_2021-12-15_115436.jpg(105.6 KB) - download Final Poster

2021/9/22 Prosthetic Hand Review

EMMALINA GROVES - Oct 17, 2021, 9:28 AM CDT

Title: Mechanical design and performance specifications of anthropomorphic prosthetic hands: A review

Date: 9/22/21

Content by: Emmalina Groves

Present: N/A

Goals: Use various prosthetics detailed in the article and compare to chosen design. Do further research on designs that match up to teams design ideas

Content:

https://www.rehab.research.va.gov/JOUR/2013/505/pdf/belter505.pdf

Abstract—In this article, we set forth a detailed analysis of the mechanical characteristics of anthropomorphic prosthetic hands. We report on an empirical study concerning the performance of several commercially available myoelectric prosthetic hands, including the Vincent, iLimb, iLimb Pulse, Bebionic, Bebionic v2, and Michelangelo hands. We investigated the finger design and kinematics, mechanical joint coupling, and actuation methods of these commercial prosthetic hands. The empirical findings are supplemented with a compilation of published data on both commercial and prototype research prosthetic hands. We discuss numerous mechanical design parameters by referencing examples in the literature. Crucial design trade-offs are highlighted, including number of actuators and hand complexity, hand weight, and grasp force. Finally, we offer a set of rules of thumb regarding the mechanical design of anthropomorphic prosthetic hands.

- Review of prosthetic hands
- All hands reviewed are total hand prosthetics and heavily electronic
- Myoelectric = externally controlled prosthetic, not driven by patient muscle strength
- All prosthetic designs are very heavily electric, so likely difficult to get any designs from this review, although the comparison methods used could be helpful during testing to generate ideas for tests(eg. Grip force, grasp speed etc)

Conclusions/action items:

Review paper once design idea is chosen, and do further research on applicable designs

2021/9/22 Thumb Design

EMMALINA GROVES - Oct 17, 2021, 9:33 AM CDT

Title: Thumb Design of an Experimental Prosthetic Hand

Date: 9/22/21

Content by: Emmalina Groves

Present: N/A

Goals: Use research to help guide design for thumb

Content:

Abstract The design of a two degree of freedom prosthetic thumb is presented. It is applied to an experimental, multi-fingered, child sized prosthetic hand. This experimental design attempts to overcome the limitations of conventional prosthetic hands, such as limited mechanical function and artificial appearance. Design considerations focus on prosthesis requirements such as small size, low weight, durability and good cosmetic appearance. The thumb design presented here is comprised of three segments that allow the thumb to curl as it flexes and straighten as it extends, while the second degree of freedom allows it to adduct and abduct (rotate). A cable system is used to actuate the thumb and provides for a compact and lightweight design. This thumb design allows for multiple grasping patterns when using the prosthesis. In combination with an adaptive grasp system (which allows different fingers to flex independently of one another), the ability of the thumb and fingers to curl, allows for multiple contact points between the fingers and the object they grasp. This allows irregularly shaped objects to be grasped more securely, and gives the resulting grasp a natural appearance.

- Specific finger design could be helpful for joint mimic
- Uses a singer motor to all fingers
- Uses a spring to start grip process on finger
- Detailed thumb design, has two rotation methods

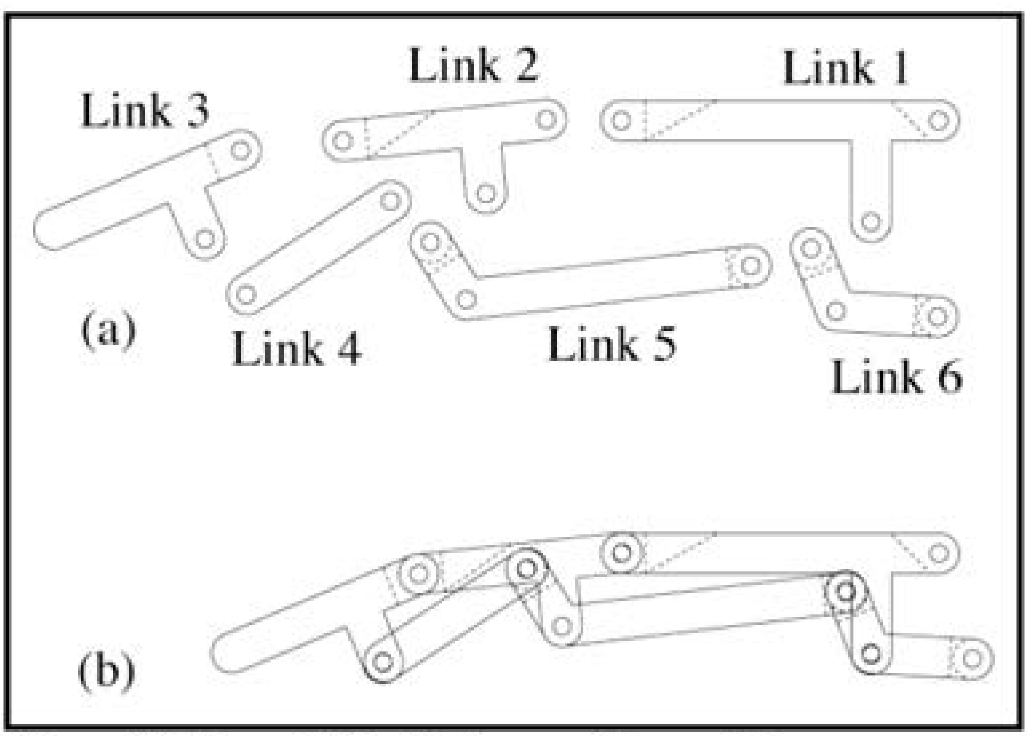


Figure 3. Finger Link Design and Assembly

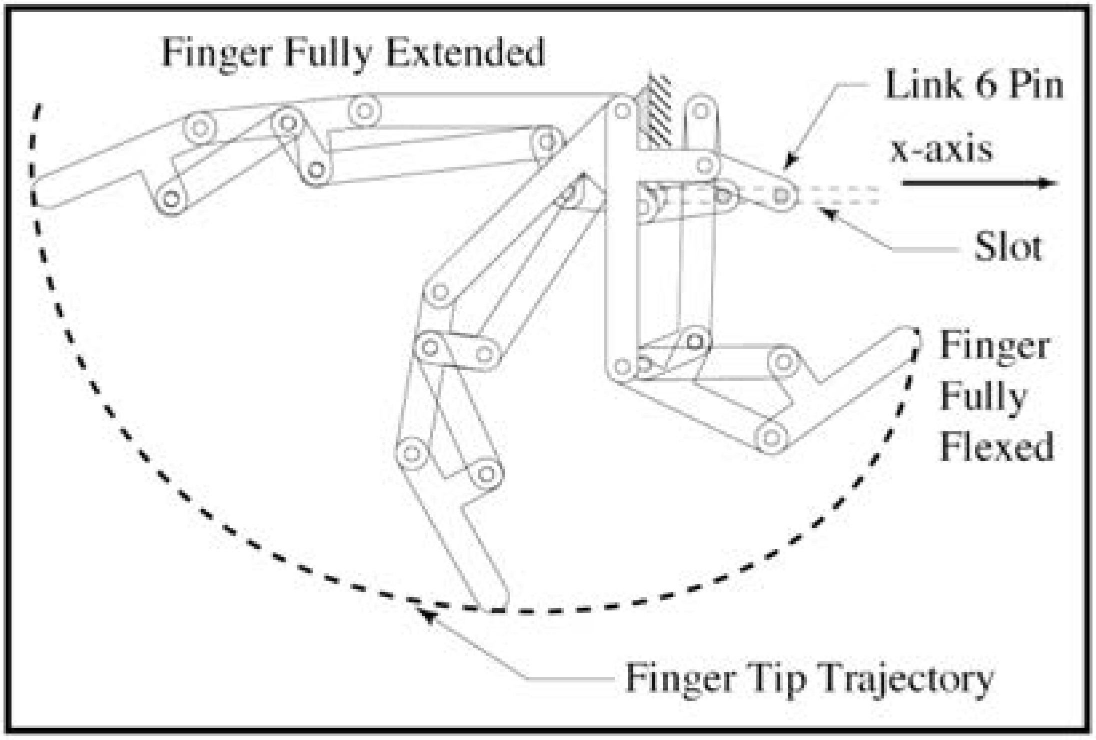


Figure 4. Single D.O.F. Finger Trajectory

Conclusions/action items:

Use Detailed mechanism of basis of solidworks design for thumb

2021/9/22 3D Printed Thumb

EMMALINA GROVES - Oct 17, 2021, 9:48 AM CDT

Title: Three-dimensional printed prosthesis demonstrates functional improvement in a patient with an amputated thumb: A technical note

Date: 9/22/21

Content by: Emmalina Groves

Present: N/A

Goals: Understand Thumb design in article and use relevant information/techniques during designing and prototyping

Content:

https://journals.sagepub.com/doi/abs/10.1177/0309364616679315?casa_token=_Ly8yWAuFdQAAAAA%3AUP4kIJDwi4Dod8TjVKVLmG0FVTH84omFjDpWVm8u7_I2QxdjfNqddMbprxqNlvL-uWtWoGpTROHq&journalCode=poia

Abstract

Background and Aim:

Three-dimensional printer is widely used in industry, biology, and medical fields. We report a finger prosthesis produced by a three-dimensional scanner and printer for a 67-year-old man with a right thumb amputation above the metacarpophalangeal joint.

Technique:

His right amputated and left intact hands were scanned with a three-dimensional scanner, and the left-hand image was rotated to the right side to design the right thumb prosthesis. The designed prosthesis was printed with a three-dimensional printer using the fused filament fabrication output system.

Discussion:

The Jebsen–Taylor hand function test and Box and Block Test scores improved after application of the prosthesis. Most Quebec User Evaluation of Satisfaction with Assistive Technology results were “very satisfied,” and most Orthotics and Prosthetics Users’ Survey results were “very easy.” Preparing the prosthesis made by three-dimensional scanner and three-dimensional printer was faster and cheaper than preparing a conventional prosthesis.

Clinical relevance

Using three-dimensional scanning and printing technique, we can easily produce specifically shaped finger prostheses for specific movements in amputated patients with low cost.

**rest of article unavailable, but due to relevance Included In research notes Incase worth obtaining In the future

Conclusions/action items:

See if it is important to obtain rest of the article

2021/9/22 e-NABLE The Future

EMMALINA GROVES - Oct 16, 2021, 7:43 PM CDT

Title: e-NABLE

Date: 9/22/21

Content by: Emmalina Groves

Present: N/A

Goals: Research competing design that could have mechanisms useful to project

Content:

https://enablingthefuture.org/shop/

- Low cost 3d printed deigns
- Use wrist flexion to generate finger movement
- Cannot use design for our patient because for amputees with no hand, not partial

e NABLE statement:

"e-NABLE is an online global community of “Digital Humanitarian” volunteers from all over the world who are using their 3D printers to make free and low-cost prosthetic upper limb devices for children and adults in need. The open-source designs created by e-NABLE Volunteers help those who were born missing their fingers and hands or who have lost them due to war, natural disaster, illness or accidents."

Conclusions/action items:

Research into marketed designs from enable to see if mechanisms for flexion are applicable to design

2021/9/27 GrabCAD

EMMALINA GROVES - Oct 16, 2021, 7:53 PM CDT

Title: GrabCAD prosthetic hand design- Hook Hand

Date: 9/27/21

Content by: Emmalina Groves

Present: N/A

Goals: Use hook hand design to inspire Solidworks model for prosthetic design

Content:

Has flexion/extension capabilities could use for Solidworks design

Conclusions/action items:

alter design in solidworks

2021/9/27 NIH 3D Print Exchange

EMMALINA GROVES - Oct 16, 2021, 8:00 PM CDT

Title: NIH 3D Print Exchange

Date: 9/27/21

Content by: Emmalina Groves

Present: N/A

Goals: Use NIH Print exchange as a resource if any designs are applicable to Soldiworks design

Content:

statement from website:

"

3D-printable prosthetics are changing the face of medicine, as engineers and physicians are able to develop prosthetics that are fully customized to the wearer. Consumer 3D printing is leading to an even bigger revolution: "DIY" assistive devices that can be printed by virtually anyone, anywhere.

e-NABLE is a network of passionate volunteers using 3D printing to give the World a "Helping Hand." They support the Maker Movement in mechanical hands by bringing together designers, engineers, physicians, 3D print enthusiasts, families and amputees, to create, innovate, re-design and *share* 3D-printable prosthetics. The e-NABLE "Family Tree" shows just how powerful open source, collaborative design can be.

The goal of this collection is to provide a central repository for all e-NABLE models and derivatives from users, along stories and print information from the e-NABLE community. The e-NABLE network includes thousands of individuals from around the globe. Connect with the community and find out how you can contribute by joining e-NABLE Google+ group.

Want to customize your own e-NABLE device? e-NABLE's "Handomatic" allows you to customize STL files with the proper model and dimensions for printing your own e-NABLE hand. Be sure to read the e-NABLE Device Safety Guidelines Statement before you use an e-NABLE prosthetic device."

Conclusions/action items:

use website as a resource if needed during design process

2021/9/27 Arm Dynamics

EMMALINA GROVES - Oct 16, 2021, 8:16 PM CDT

Title: Arm Dynamics

Date: 9/27/21

Content by: Emmalina Groves

Present: N/A

Goals: Use Arm Dynamics as comparable product

Content:

https://www.armdynamics.com/research-and-technology/prosthetic-technology

Arm Dynamics has range of prosthetics including: Passive, Body-Powered, Myoelectric, TMR, Osseointegration

Depending on design choices, specific types of prosthetic will be comparable.

Conclusions/action items:

Use as future reference when needed

2022/10/6 SolidWorks Bend Mechanism

EMMALINA GROVES - Dec 14, 2021, 11:09 AM CST

Title: Solidworks Bend Mechanism

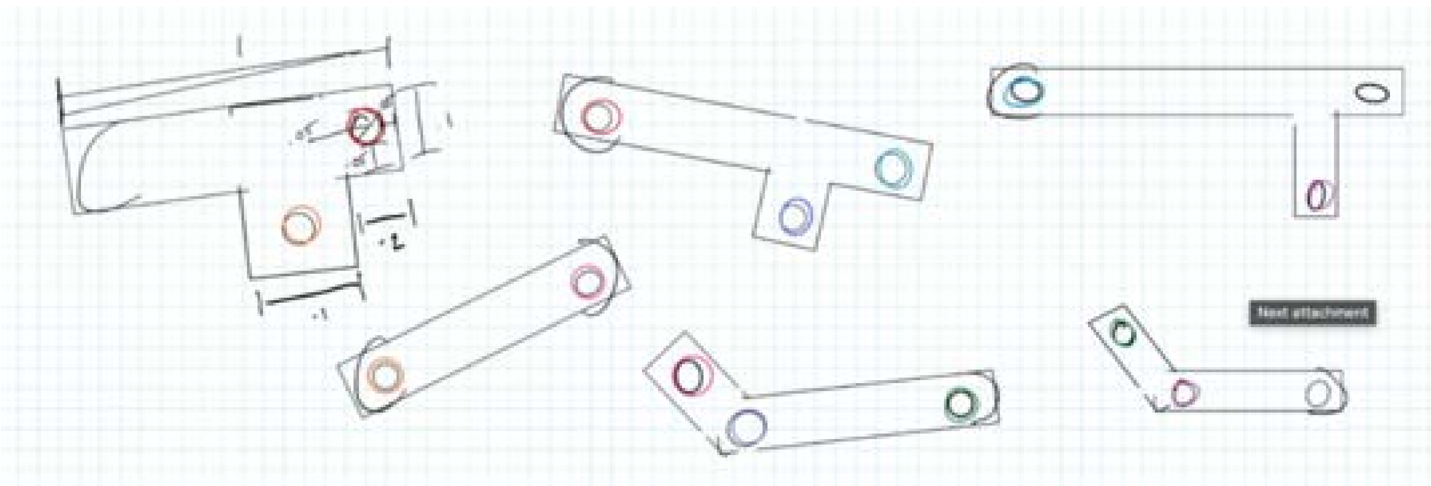
Date: 10/6/21

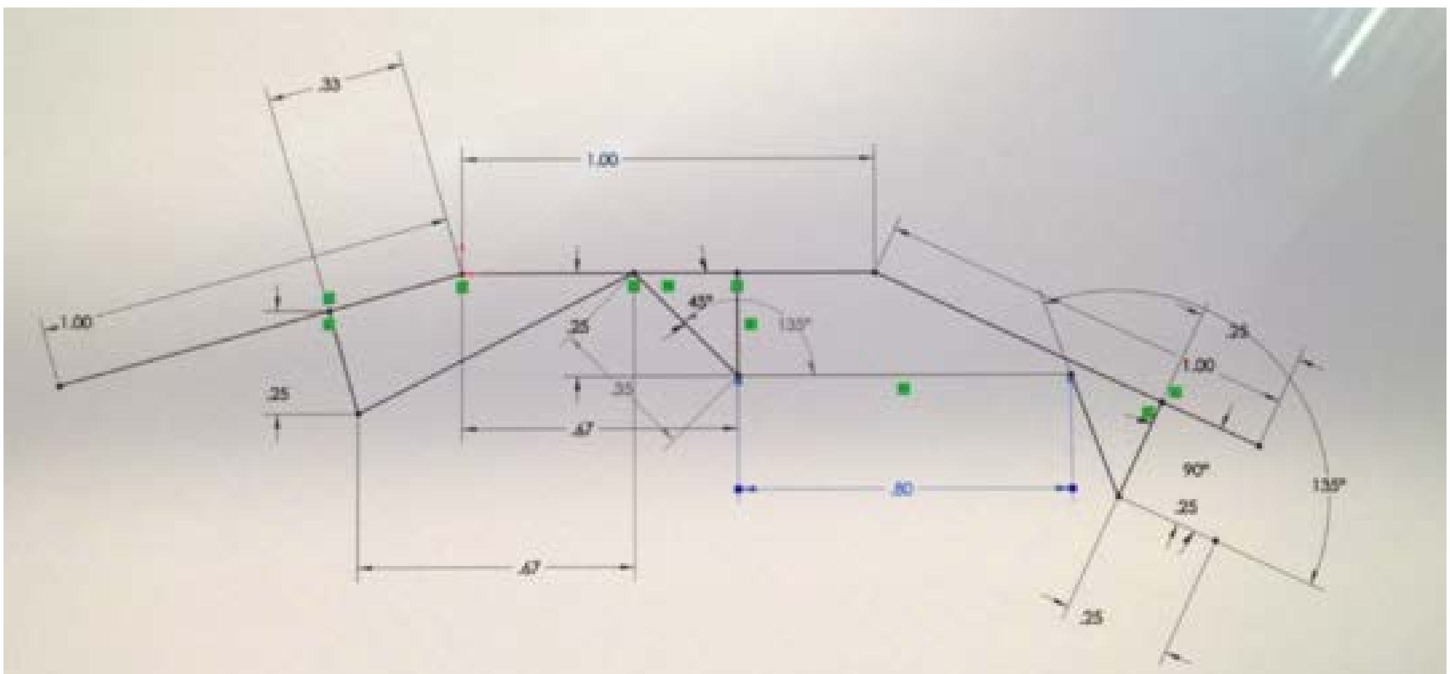
Content by: Emmalina Groves

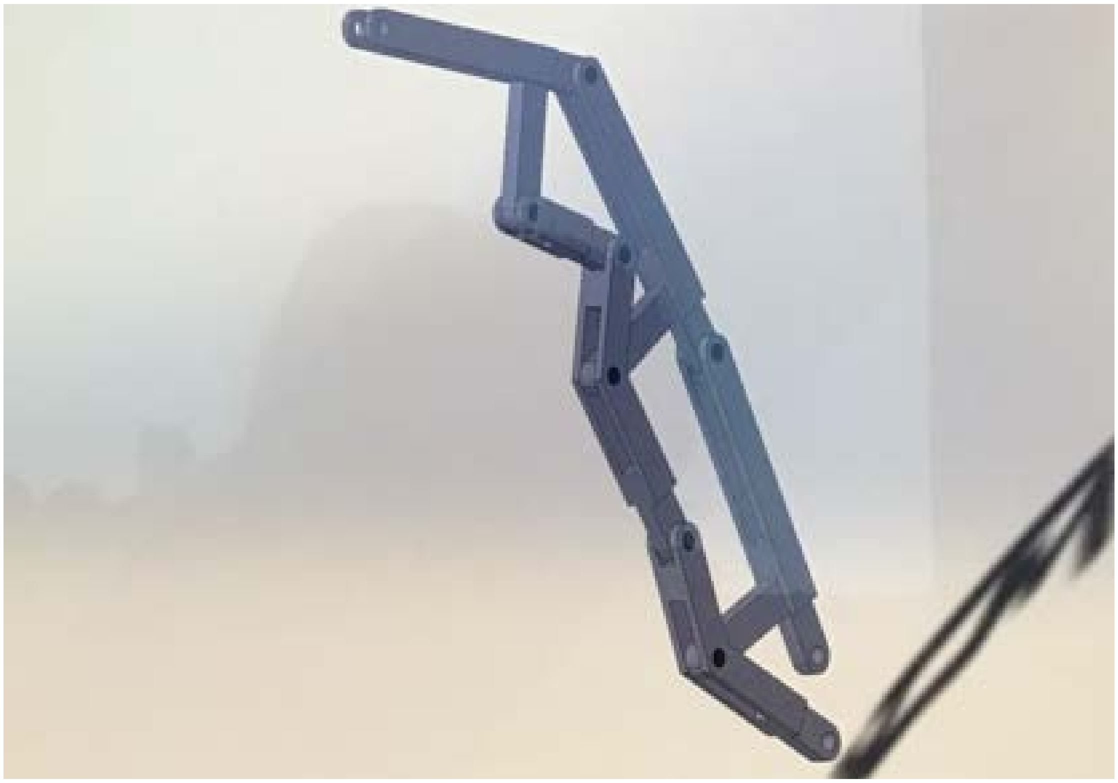
Present: N/A

Goals: Use Solidworks Design as basis on mechanics for thumb

Content:







Conclusions/action items:

Integrate design into possible motor mechanism. Attach thumb to a stiff cuff for stability and to a linear actuator on proximal end. 3D pring the design and assemble pieces in order to figure out what edits need to be made for future model. Take note of adjustments and edit solidworks design. Known needed adjustments: need a better tolerance on pieces that will fit together.

2021/10/27 Solidworks + Cuff design Idea

EMMALINA GROVES - Dec 14, 2021, 11:24 AM CST

Title: Solidworks + Cuff Design

Date: 10/27/21

Content by: Emmalina Groves

Present: N/A

Goals: Find a way to incorporate the solidworks thumb into a wrist cuff that connects to the motor.

Content:

Aspects of the design:

1. **3D printed solidworks design of mechanical thumb**
2. **Cuff for attachment to the patient's wrist, and to attach other components to**
3. **Linear Motor- will attach to the thumb, arduino, and cuff**
4. **Arduino- attached to the motor, flex sensor, and cuff**
5. **Flex sensor- attached to the arduino. Need a way to stabilize on the wrist**

Image: Drawing of how pieces of the design will fit/work together.

Conclusions/action items:

Find a good material to create a stable cuff out of. Start to work on fitting the solidworks model to attach well to the linear motor. Use current 3D printed thumb model to begin prototyping this design and discover what areas of the design need to be adjusted for this to be feasible.

2021/11/16 Thumb Re-design Notes

EMMALINA GROVES - Dec 14, 2021, 11:46 AM CST

Title: Thumb ReDesign

Date: 11/16/21

Content by: Emmalina Groves

Present: N/A

Goals: Make changes to the solidworks model of the mechanical thumb that will allow for better function and more appropriate dimensions

Content:

Image: notes from design ideas for necessary changes.

Summary of changes:

1. Clevis pins will be used instead of printed pins. Clevis pins to be ordered with dimensions specified above. Need to alter the hole sizes in the pieces to fit the clevis pins.
2. Change width of the pins to be .58 to fit well with clevis pins and add sturdiness to design
3. Lengthen pieces in x-axis direction to increase total length of the design.

Conclusions/action items:

Implement these changes into solidworks part designs. Make an assembly with the changed pieces to test that they fit together the intended way. If successful, 3D print the solidworks pieces and begin assembly of the design. Take note of any issues and future changes that would increase function/strength/ROM of the design.

2021/12/7 Printed Design

EMMALINA GROVES - Dec 14, 2021, 12:13 PM CST

Title: Printed Design + Linear Motor

Date: 12/7/21

Content by: Emmalina Groves

Present: Team

Goals: Use 3D printed thumb in conjunction with linear motor to determine adjustments to the design that are necessary for the final prototype.

Content:

Image preview

Figure: Preliminary prototype of thumb mechanism.

Pictured:

1. 3D printed thumb
2. Linear Motor- attached to the thumb
3. thermoformed cuff
4. 3D printed model of patient's hand

Note: pieces on the thumb model shown above are not in the same order as shown in solidworks models. Pieces were moved around to test various lengths as models for future sizing changes.

Conclusions/action items:

Adjust the heigh of the Solidworks design so it fits thehand model better. Currently the thumb is too short, and when flexed goes about 50% the height of the distance necessary. Need to designthe thumb to flex and meet the pinky to be able to hold things well. Make these changes in solidworks and then reprint the design with longer features.

2021/12/9 Final Prototype

EMMALINA GROVES - Dec 14, 2021, 12:29 PM CST

Title: Final Thumb Prototype

Date: 12/9/21

Content by: Emmalina Groves

Present: Team

Goals: Record design for final prototype

Content:

Figure: Final prototype of thumb mechanism.

Featured Components:

1. Thermoformed Cuff
2. Linear Actuator

3. Velcro straps
4. 3D printed Thumb Mechanism

Notes about the thumb mechanism: Pieces from two printed models were used to get the length desired for the prototype. Various models can be seen in different colors above. The most recent design in red, and the black piece is from an older model but was incorperated for more extension.

Conclusions/action items:

This is the design chosen to be modeled at the presentation, but modifications must be made for next semester. Length of design needs to be increased further. Another change necessary is more stability and a better thumb/cuff interface. To do this, need to fix the piece that rests on the cuff to stabilize the thumb with the cuff. Another needed modification is to adjust design to contain as much room in the palm as possible. Do not want the design to house components in an area that should be devoted to gripping objects. For the future: find a way to move pieces as much "out of the way" as possible.

2021/12/6 Solidworks Drawing

EMMALINA GROVES - Dec 14, 2021, 12:05 PM CST

Title: Solidworks Drawing

Date: 12/6/21

Content by: Emmalina Groves

Present: N/A

Goals: Define the Solidworks Model

Content:

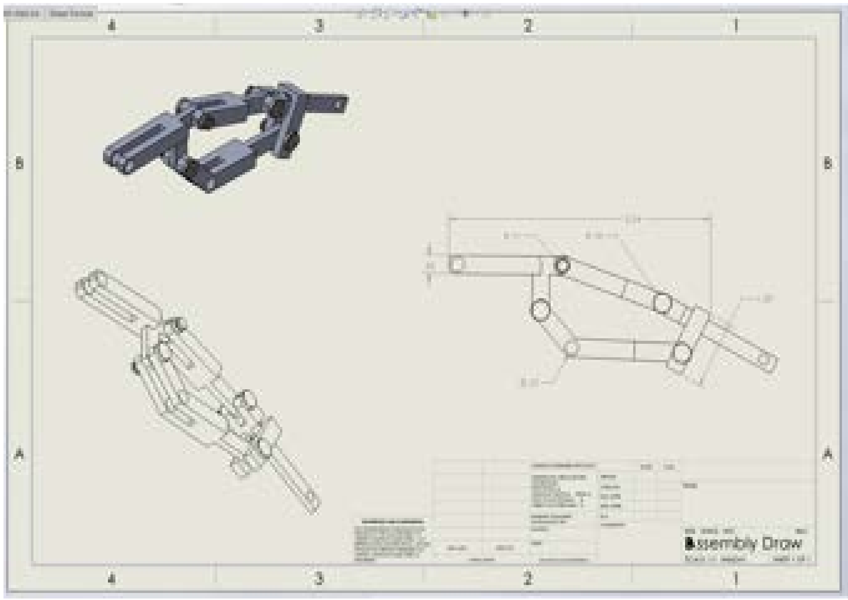


Image: Solidworks thumb design with adjusted width and fixed pin sizes

Conclusions/action items:

Print soldiworks design and assemble. Used assembled model in prototype. Note any issues with the prototype(mechanical) and adjust the model in solidworks. Likely this model will be sufficient for prototype this semester, but it is important to note needed adjustments for next semester. Emphasis on adjustedments possible to increase strength and stability and emphasis on adjustments to increase range of motion with consistent linear actuator movement.

2021/12/6 L Shape

EMMALINA GROVES - Dec 14, 2021, 12:41 PM CST

Title: Drawing of L Shape

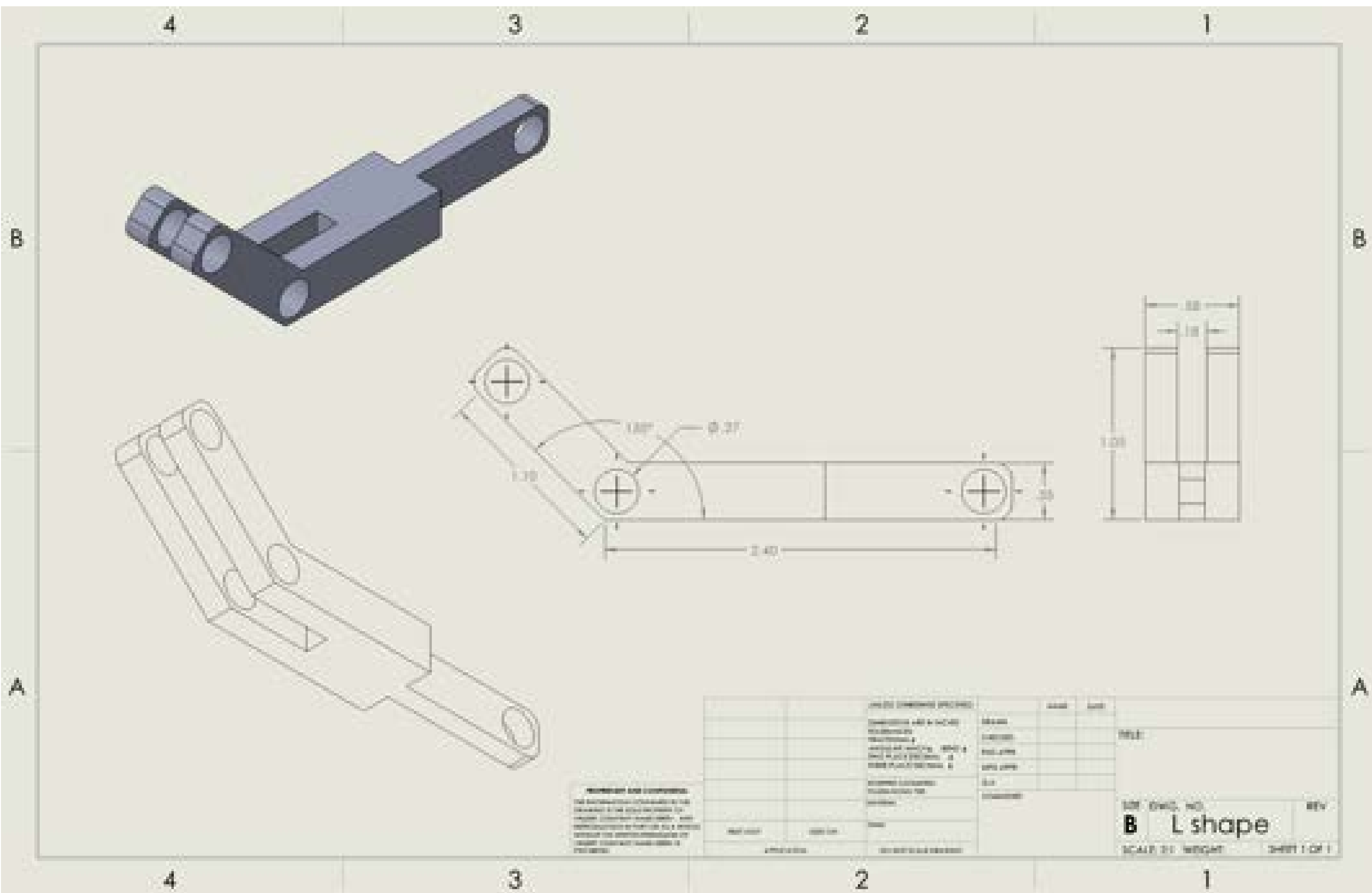
Date: 12/6/21

Content by: Emmalina Groves

Present: N/A

Goals: Characterize pieces that are used in the thumb design. Use dimensions for future design changes as a reference.

Content:



Conclusions/action items:

Make changes to thumb design based on currently existing parts. Keep aspects of the design that worked well and tailor parts that need changes. Specifically, look into changing the angle with the L piece and see if the range of motion is decreased or increased with this change.

2021/12/6 Piston

EMMALINA GROVES - Dec 14, 2021, 1:10 PM CST

Title: Piston Drawing

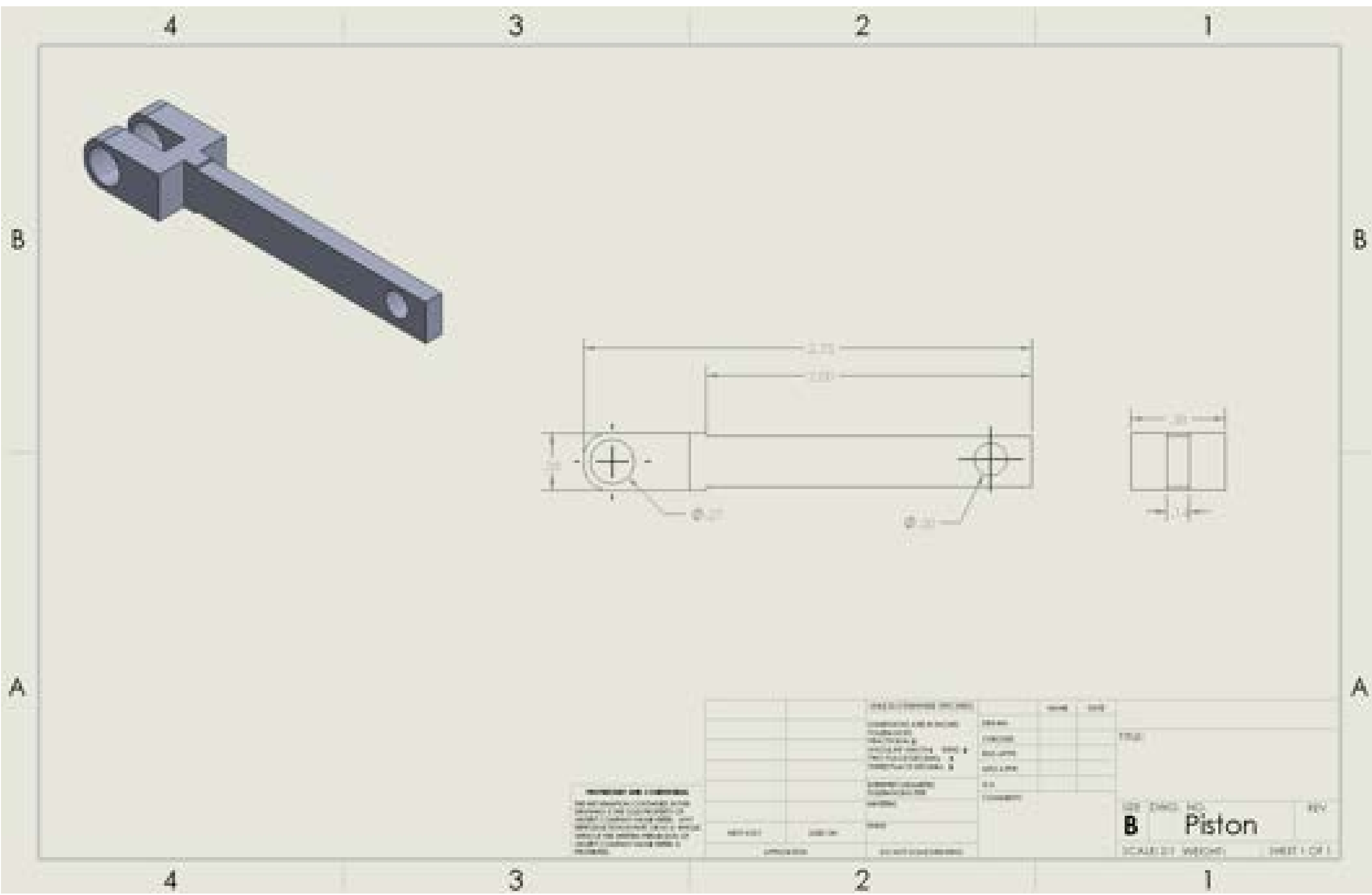
Date: 12/6/21

Content by: Emmalina Groves

Present: N/A

Goals: Characterize Pieces in final SolidWorks design in order to make future edits easier.

Content:



Conclusions/action items:

Use dimensioned model of piston to work off of if future changes are needed next semester. Specifically, making long end of piston thinner will allow for more flexible movement on the piece. Size attachment to the linear motor is good but piece had to be sanded to attach well. Make room between hole and end of piece smaller for better attachment.

2021/12/6 T Shape

EMMALINA GROVES - Dec 14, 2021, 1:28 PM CST

Title: T Shape

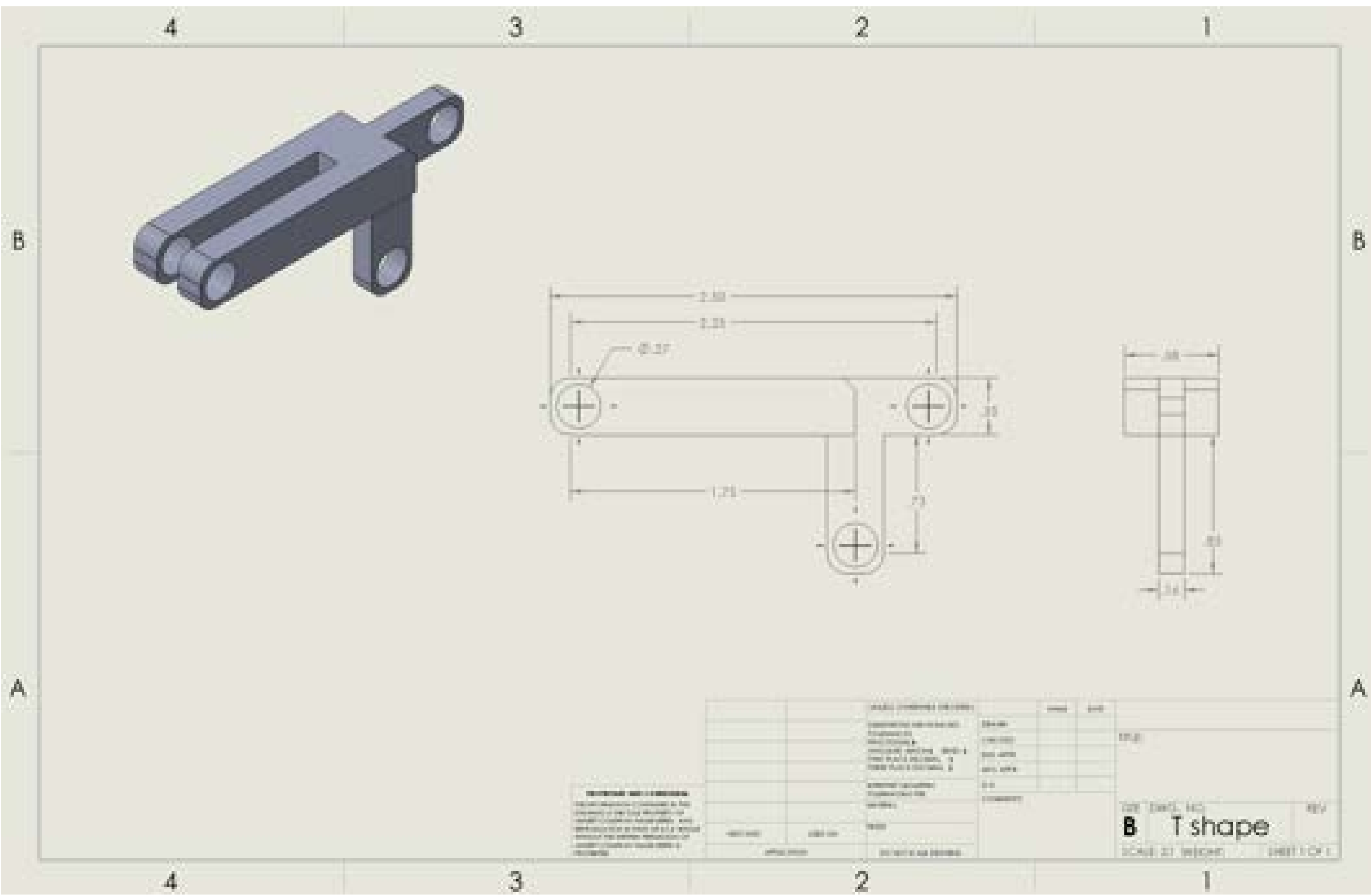
Date: 12/6/21

Content by: Emmalina Groves

Present: N/A

Goals: Characterize pieces of Solidworks design

Content:



Conclusions/action items:

Use Dimensioned sketches of solidworks parts as basis of updating the design next semester. For the T Shape piece extension of perpendicular part might help with flexion movement. Piece may need resizing and extending for lengthening of the full design.

2021/12/6 Cuff Attachment

Title: Cuff Attachment

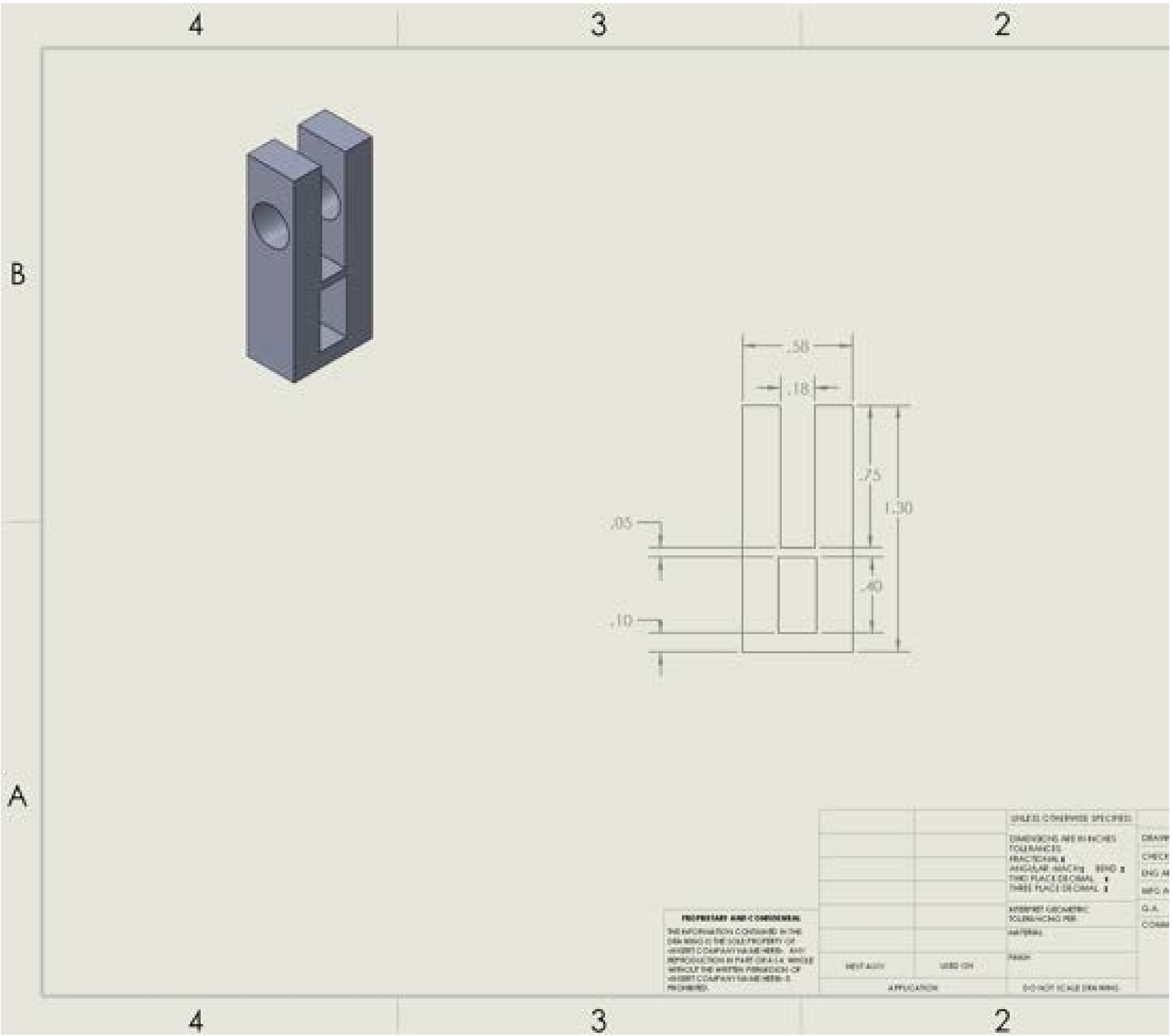
Date: 12/6/21

Content by: Emmalina Groves

Present: N/A

Goals: Define the solidworks model in order to make any future changes easier.

Content:



Conclusions/action items:

Increase the rectangular hole size in order to make motion of the piston smoother. Also, increase the size of the base where the piece will interface with the cuff. A larger base will create a mor
curvature of the cuff.

Musculoskeletal Anatomy

STEPHANIE SILIN - Oct 20, 2021, 10:16 AM CDT

Title: Musculoskeletal Anatomy

Date: 9/17/2021

Content by: Stephanie Silin

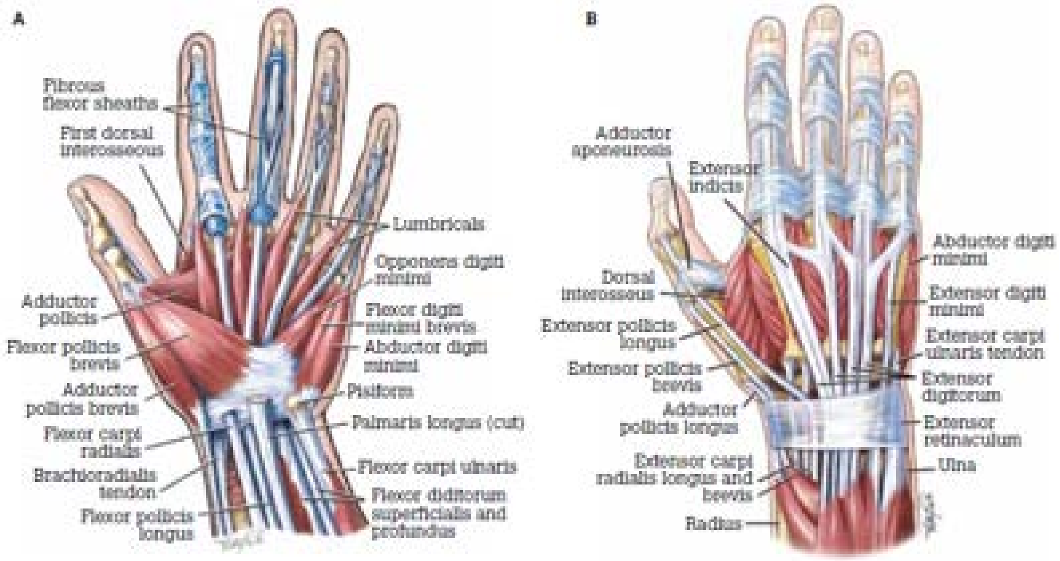
Present: None

Goals: Document hand anatomy

Content:

https://www.google.com/url?sa=i&url=https%3A%2F%2Fmurdochorthopaedic.com.au%2Four-surgeons%2Fpaul-jarrett%2Fpatient-information-guides%2Fhand-wrist-anatomy%2F&psig=AOvVaw2uK9Y4wPYFaiIq80yTZO1D&ust=1632429238126000&source=images&cd=vfe&ved=0CAwQjhxqFwoTCPivuaO3k_MCFQAAAAAdAAAAABAJ

https://www.racgp.org.au/afp/2012/april/hands,-fingers,-thumbs/



- The thumb itself has 3 distinct bones and 2 joints

https://www.researchgate.net/figure/Degrees-of-freedom-of-the-wrist-and-fingers-joints_fig1_264907843

- The Thumb has 3 total degrees of freedom:
  - One at the phalangeal joint or more distal joint
    - Flexion/Extension
  - Two at the metacarpal joint
    - Adduction/Abduction
    - Flexion/Extension
    - Some sources consider the circumduction at this joint another degree of freedom, however this not being a ball and socket joint, but rather a saddle-joint, this circumduction is just a combination of the other two degrees of freedom and is not a 3rd rotation

Conclusions/action items:

Begin documentation of the skin and innervation

Integument and Innervation

STEPHANIE SILIN - Oct 20, 2021, 10:47 AM CDT

Title: Integument and Innervation

Date: 9/30/2021

Content by: Stephanie Silin

Present: N/A

Goals: Understand innervation and integument layers to understand the patient's skin graft

Content:

https://www.google.com/url?q=https://opentextbc.ca/anatomyandphysiologyopenstax/&sa=D&source=docs&ust=1634746762014000&usg=AOvVaw1x_51o0FvdJPrRgaJA4Efa

The innervation of the integument allows fine touch reception, pain and temperature reception, as well as deep touch sensation. This allows humans to sense their surroundings and respond to them.For this humans have many kinds of reception including: tactile receptors (fine touch and low frequency vibrations), free nerve endings (pain and temperature), Bulbous corpuscles (continuous deep pressure), lamellated corpuscles (deep pressure and high frequency vibrations), and others. These are all located in different layers of the integument. The most superficial layer is the epidermis, which itself is subdivided into 4 layers on an area like the arm, but 5 for thick skin such as on the palms of the hands. The deepest layer of the epidermis, and the layer in which innervation begins is the stratum basale. After the epidermis is the dermis, containing the papillary layer (more superficial), and the reticular layer. The last layer of the integument is the hypodermis or subcutaneous layer. Which mostly functions to connect the skin, bones, and muscles. This layer also functions to store fat and acts as cushioning.

Tactile cells are found in the stratum basale, tactile discs in the epidermal-dermal junction, and tactile corpuscles in the papillary dermis. Free nerve endings are scattered throughout the stratum basale and papillary dermis. Bulbous corpuscles are found throughout the dermis, and Ruffini corpuscles are in the reticular layer of the dermis and in the hypodermis. Keeping the light touch receptors and the free nerve endings more superficial is important because the body can respond more quickly to changes in temperature, and it allows better sensation of fine touch. However, the more superficial layers are less vascularized, thus if being in a superficial layer is less important to function, the receptors will be in deeper layers.

https://www.orthopaedicmedicineonline.com/downloads/pdf/B9780702031458000727_web.pdf

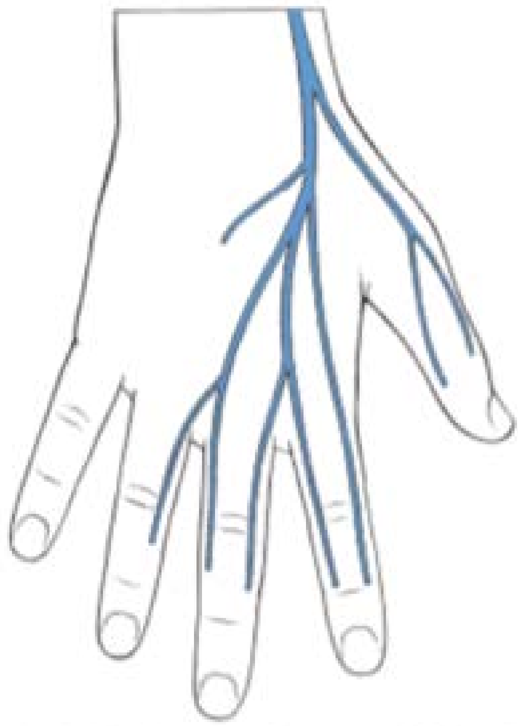


Fig 19 • Terminal digital branches of the superficial radial nerve.

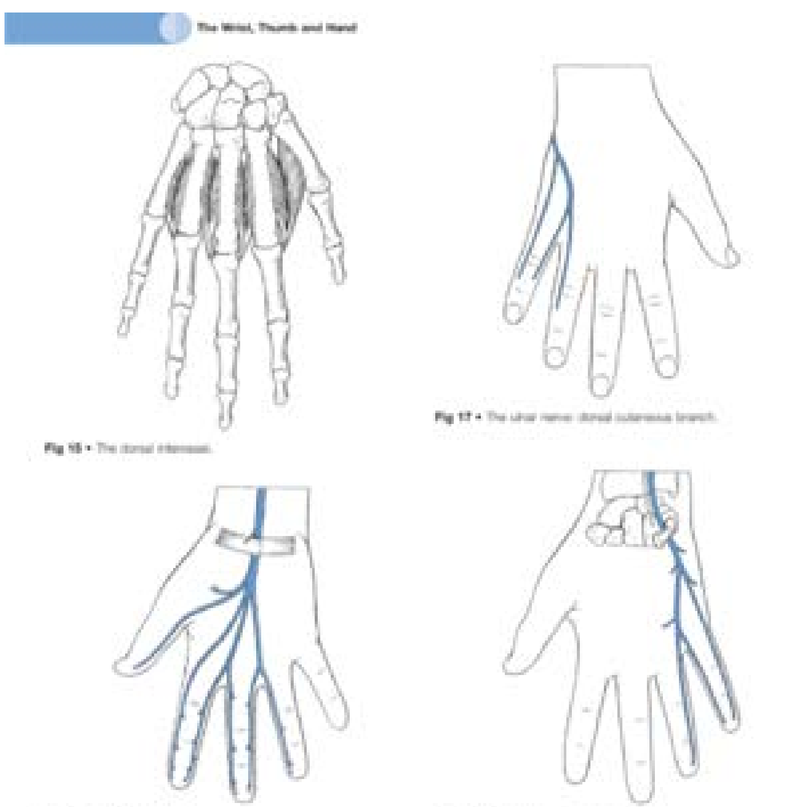


Fig 15 • The dorsal interossei.

Fig 17 • The ulnar nerve: dorsal cutaneous branch.

Fig 16 • The median nerve.

Fig 18 • The ulnar nerve: palmar branch.

https://www.sciencedirect.com/science/article/pii/S0738081X04001373

Skin grafts are either:

- Thin
    - Includes the epidermis and a small amount of the dermis
    - Having some dermal layer is important for skin grafts
- Thick

    - Including all of the dermis and the epidermis
    - This would not preserve many of the receptors and in fact would only leave the deep touch receptors in the hypodermis

Conclusions/action items:

It is likely that the patients slight loss of sensation was due to loss of free nerve endings and tactile receptors in the epidermis and papillary layer of the dermis when the skin graft was done. However, as skin grafts typically preserve the hypodermis, and sometimes the majority of the dermis but not always, the patient still has deep pressure sensation, additionally since the patient was able to feel some pain, it is likely some of his dermis was preserved in the skin graft and therefore he may have some (few, but present) tactile receptors as well. However this is definetly not something to 'bank on' and the team definetly needs to ensure the fit an comfort of a prosthetic for this patient is good, because losing more of the pain receptors could mean the patient fails to notice blistering/bruising when using the prosthetic for long periods of time. This would be bad because the patient really doesn't need another infection in this area, so he would need to take a break from the prosthetic if this occurred.

Amputee Population

STEPHANIE SILIN - Oct 20, 2021, 10:32 AM CDT

Title: Amputee Population in the United States

Date: 10/10/2021

Content by: Stephanie Silin

Present: N/A

Goals: Determine rate of hand/finger amputations and commonality

Content:

Amputations are a common occurrence in the United States with between 500,000 and 100,000 limb amputations (including trans-carpal amputations) occurring per year [1]. As of 2008 approximately 1.7 million people in the United States are amputees and of those people an estimated 500,000 have minor upper limb amputation, defined as amputation at the fingers, the hand, or the forearm distal to the elbow [2].

The amputated population is only expected to increase over time, while this is both due to an increased in population and an increase in vascular related amputations due to diabetes, this is still expected to increase for trans-carpal amputations as well, just to a lesser extent [2].

The most common ways someone becomes an amputee include: trauma, vascular disease, infection, congenital deformity, and malignancy [1].

[1] https://www.google.com/url?q=https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6173827/&sa=D&source=docs&ust=1634746762015000&usg=AOvVaw1kWrAku98jTtdGiELTt9bI

[2] https://www.google.com/url?q=https://www.sciencedirect.com/science/article/pii/S0003999307017480?casa_token%3DWUV7525Q9GYAAAAA:WDIh-WMRZusX7JqeFsDYZwR_5GbGcc1IKIMLPNYGhVEJNduPtDM8ZLQniDWT2t5zH3XHR_X2jMY&sa=D&source=docs&ust=1634746762016000&usg=AOvVaw11Cj6ZZyN0j6dYAoTZuVkk

Conclusions/action items:

There are a lot of people with amputated limbs in the US alone, and likely a lot of people with medical debt/without insurance that would benefit from a cheaper prosthetic.

Uninsured Population

STEPHANIE SILIN - Oct 20, 2021, 10:53 AM CDT

Title: Uninsured Population in the US

Date: 10/11/2021

Content by: Stephanie Silin

Present: N/A

Goals: Determine the percentage of the uninsured population

Content:

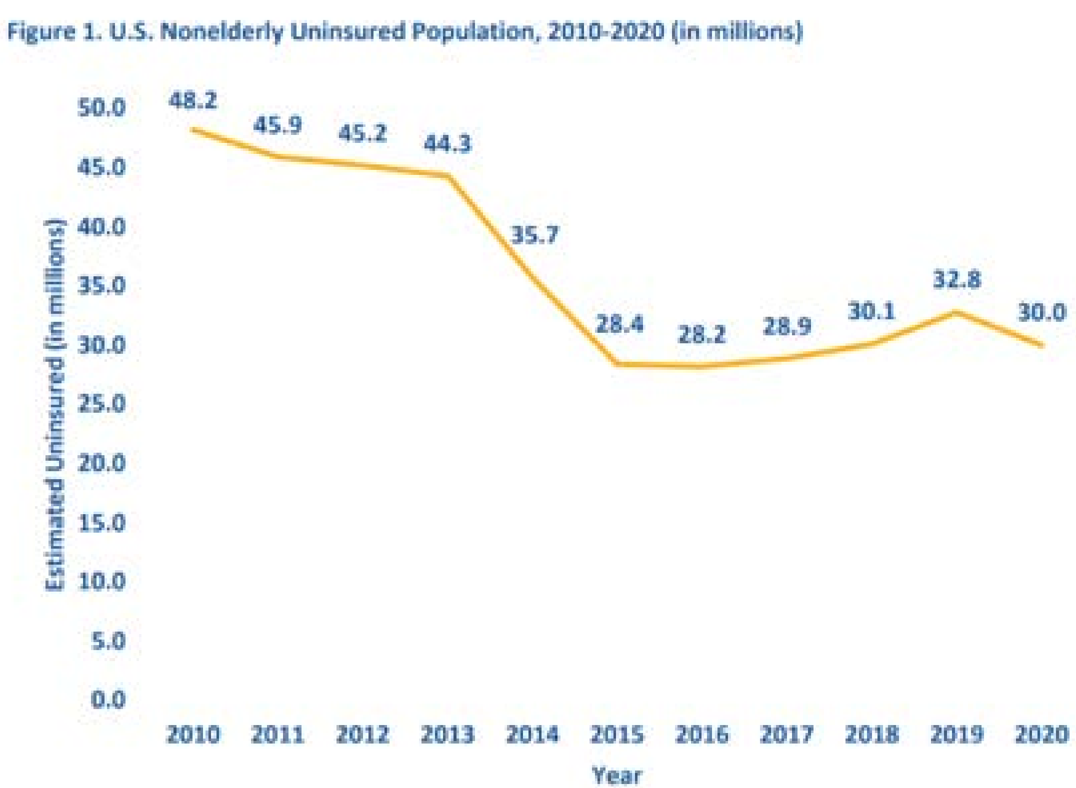
2019: US census reports 8.0% of people were uninsured for the entire year [1]

2020: US census reports 8.1% of people uninsured for the entire year [1]

2019: CDC reports at the time of a given interview 14.7% of people aged 18-64 are uninsured [2]

Graph of Insured people over time [3]:

- Shows while uninsured population was decreased since 2010, it has been rising again after 2016



[1] https://www.google.com/url?q=https://www.census.gov/library/publications/2021/demo/p60-274.html&sa=D&source=docs&ust=1634746762017000&usg=AOvVaw2s5nnzLa05ZQXTo7HBg2jc

[2] https://www.google.com/url?q=https://www.cdc.gov/nchs/fastats/health-insurance.htm&sa=D&source=docs&ust=1634746762017000&usg=AOvVaw3fX_RAaFvcf9Kf_XJJ1LKN

[3] https://www.google.com/url?q=https://aspe.hhs.gov/sites/default/files/private/pdf/265041/trends-in-the-us-uninsured.pdf&sa=D&source=docs&ust=1634746762019000&usg=AOvVaw2rLlykB4bS7NLO-oxpXmKr

Conclusions/action items:

There are a lot of people who could benefit from cheaper functional prosthetics.

Prosthetic Forces

STEPHANIE SILIN - Oct 20, 2021, 2:20 PM CDT

Title: Prosthetic Forces

Date: 9/17/2021

Content by: Stephanie Silin

Present: N/A

Goals: Understand force outputs/required forces for a prosthetic

Content:

A comparison of the grip force distribution in natural hands and in prosthetic hands
https://www-tandfonline-com.ezproxy.library.wisc.edu/doi/abs/10.1080/09638280410001704278

Contact forces of up to 24.7 N are applied by the middle and distal phalanges of the index finger, middle finger, and thumb of standard prosthetic hands, whereas forces of up to 3.8 N are measured for human hands. The maximum contact forces measured in a prosthetic hand with an adaptive grasp are 4.7 N. The joint torques of human hands and the adaptive prosthesis are comparable.

Conclusions/action items:

Figure out a way to meet that need

Passive/Cosmetic Prosthetics

STEPHANIE SILIN - Oct 20, 2021, 1:41 PM CDT

Title: Passive/Cosmetic Prosthetics

Date: 9/20/201

Content by: Stephanie Silin

Present: N/A

Goals: Find current passive prosthetics options and related interest in them

Content:

About Passive Prosthetics:

https://journals.sagepub.com/doi/full/10.1177/0309364617691622

There are 2 types of passive prosthetics: static and adjustable. The static kinds can not be moved at all whereas the adjustable ones can be. One in three people with a limb deficiency uses this type of prosthetic.

The main reasons ranked for this type of of prosthetic is comfort and cosmesis. These are also more likely to be recomended to recent amputees and/or children as they need adjustment to a prosthetic.

Materials:

https://ieeexplore-ieee-org.ezproxy.library.wisc.edu/abstract/document/4115645

Materials they used in this study:

- Technogel® (Royal Medica, s.n.c., Italy)
- Silicone (GLS 40, Prochima, s.n.c., Italy)
- Polyurethane (Poly 74–45, Polytek Devt Corp, USA)

Options and Price:

https://www.ottobockus.com/prosthetics/upper-limb-prosthetics/solution-overview/passive-arm-prostheses/

- Static
- It's a little interesting they have a whole page dedicated on how to be persistant with your insurance company to get coverage

https://www.armdynamics.com/upper-limb-library/tag/passive-prosthesis

- offers both static and adjustable prosthetics

https://mcopro.com/blog/resources/arm-hand-prosthetics/

- Passive/Cosmetic prosthetic arms/hands cost around $5,000

Commentary:

The Uncanny Valley (2006):

- https://ieeexplore-ieee-org.ezproxy.library.wisc.edu/abstract/document/4115645
- Basically if something is similar to humans but doesn't mimic movement it unsettles people like prosthetic hands and corpses
- But the opposite, puppets are cool
- Skin materials
    - Soft skin:

        - Helps with grasping and manipulation
        - Can protect any sensors if there are any
        - Can increase SA of the hidden sensors
        - Good for creating friction
    - Skin color:
        - Patients prefer to not draw attention to it so it should match
    - Fingerprint features:
        - “Slip stick phenomenon” fingerprints help increase adhesion between the fingers and objects
        - Fingerprints increase tactility --not sure this is necessary don’t think we goin this hardcore--

Conclusions/action items:

Look into some non-passive devices

Body Powered Prosthetics

STEPHANIE SILIN - Oct 20, 2021, 1:57 PM CDT

Title: Body Powered Prosthetics

Date: 9/22/2021

Content by: Stephanie Silin

Present: N/A

Goals: Get a look at body-powered prosthetics

Content:

About:

- Body powered prosthetics rely on wrist motion to work and the patients own force production to move the fingers
- This only really works well for people who have wrist mobility
    - However our patient does have some wrist mobility

Materials:

https://www.rehab.research.va.gov/JOUR/2013/509/jrrd-2012-12-0223.html

- Typically metals or heavy duty plastics

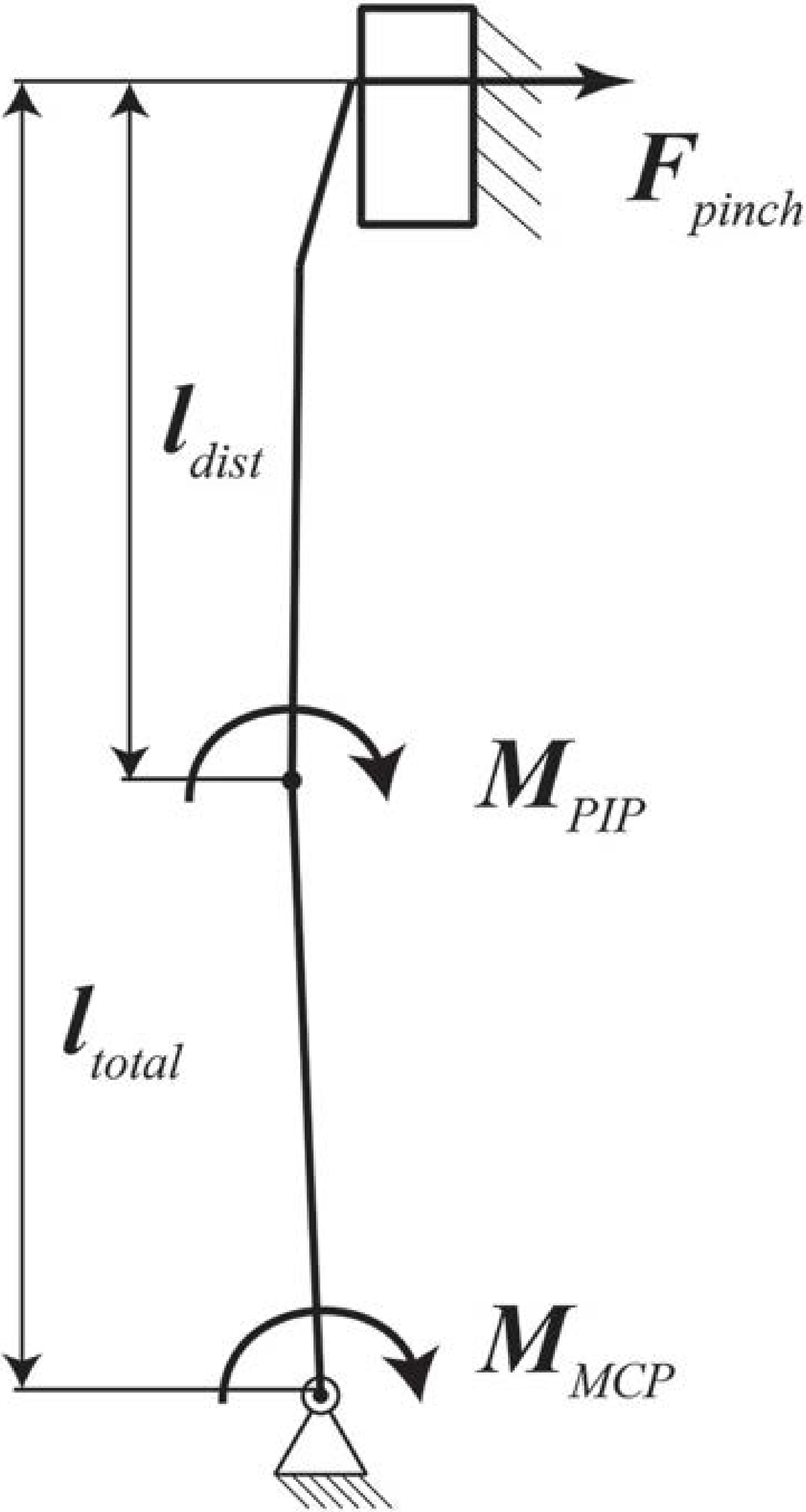
Options/Price:

https://mcopro.com/blog/resources/arm-hand-prosthetics/

- These prosthetics can cost around $10,000 which varies depending on amount of hand loss and type of prosthetic

https://www.rehab.research.va.gov/JOUR/2013/509/jrrd-2012-12-0223.html

- This link discusses 2 BP options
- BP:
    - Typical BP prosthetic hand requires up to 2,292 Nmm of energy to pinch 15 N


F pinch
l dist
M PIP
l total
M MCP


(a)
(b)


(Left is a pulley-cable finger, right is a hydraulic cylander finger)

- These options both had significant energy loss but were improvements upon existing BP prosthetics
- These were only tested with single fingers which may not be desired for this case as the patient is missing 3 fingers
- Pulley-cable required higher action force

Required work and dissipated energy for different tasks

Finger	Angle (??)	Pinch Force (N)	Glove	Work (Nmm)*	Hysteresis (Nmm)*
Pulley-Cable	0	30	Frame	858 ± 15	214 ± 15
Pulley-Cable	0	30	Frame + Glove	1,148 ± 95	431 ± 70
Pulley-Cable	90	0	Frame	111 ± 1	58 ± 1
Pulley-Cable	90	0	Frame + Glove	127 ± 10	47 ± 9
Pulley-Cable	90	30	Frame	954 ± 15	243 ± 8
Pulley-Cable	90	30	Frame + Glove	1,009 ± 26	253 ± 13
Pulley-Cable	180	0	Frame	245 ± 3	150 ± 4
Pulley-Cable	180	0	Frame + Glove	486 ± 45	288 ± 39
Pulley-Cable	180	30	Frame	1,110 ± 14	303 ± 3
Pulley-Cable	180	30	Frame + Glove	1,214 ± 57	359 ± 48
Hydraulic Cylinder	0	30	Frame	708 ± 8	211 ± 9
Hydraulic Cylinder	0	30	Frame + Glove	761 ± 7	219 ± 5
Hydraulic Cylinder	90	0	Frame	113 ± 2	106 ± 3
Hydraulic Cylinder	90	0	Frame + Glove	125 ± 4	115 ± 4
Hydraulic Cylinder	90	30	Frame	549 ± 14	251 ± 7
Hydraulic Cylinder	90	30	Frame + Glove	782 ± 20	323 ± 23
Hydraulic Cylinder	180	0	Frame	218 ± 2	188 ± 2
Hydraulic Cylinder	180	0	Frame + Glove	360 ± 19	284 ± 20
Hydraulic Cylinder	180	30	Frame	990 ± 19	439 ± 16
Hydraulic Cylinder	180	30	Frame + Glove	1,111 ± 35	513 ± 28

*Data presented as mean ± standard deviation.

Commentary:

- These prosthetics are more functional than the cosmetic ones, however they are signficantly less cosmetic, and require a large amount of energy to produce a small force
- While the patient may not need to do heavy lifting with the hand, if he does this could be a very uncomfortable option for both appearance and pressure on the wrist
- However, this provides more functionality than cosmetic and less cost than the myoelectric hands so it may be worth exploring more

Conclusions/action items:

This may be a good route to go as the pateint has some flexion of the wrist, however, it may not be enough/strong enough

Myoelectric Prosthetics

STEPHANIE SILIN - Oct 20, 2021, 2:18 PM CDT

Title: Myoelectric Prosthetics

Date: 9/22/2021

Content by: Stephanie Silin

Present: N/A

Goals: Get an idea of current popular myoelectric prosthetics

Content:

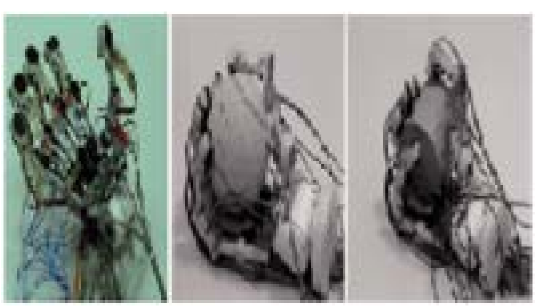
Price:

https://mcopro.com/blog/resources/arm-hand-prosthetics/

Typical cost of these devices is between $40,000 and $100,000

Models:

Recent Advancements in Prosthetic Hand Technology (2016 (21 April)):

- https://www-tandfonline-com.ezproxy.library.wisc.edu/doi/abs/10.3109/03091902.2016.1167971
- Timeline:
  - Figure 1. Developed robot hand by Lee et al. [2].
    - 
  - Figure 2. The Zurich–Tokyo hand, as inspired by the muscle–tendon system of the human hand.[3] (Left): Hand structure. (Middle and Right): Final grasp of different objects.
    - 
  - Figure 3. SQUSE lifelike robot hand.[4]

- 

- Figure 4. I-LIMB ULTRA hand, a formal way to categorise grasps.[6]

- 

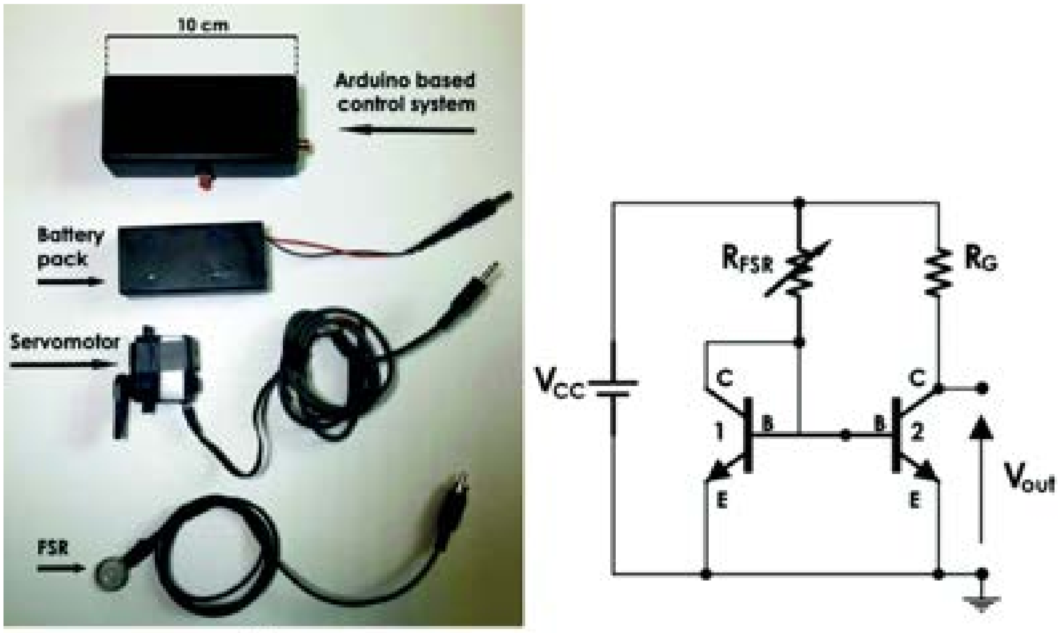
- Figure 5. Southampton Remedi Hand with six independent movements.[15]

- 

Robotic Hand with Locking mechanism using TCP muscles for applications in prosthetic hands and humanoids

- https://www-spiedigitallibrary-org.ezproxy.library.wisc.edu/conference-proceedings-of-spie/9797/1/Robotic-hand-with-locking-mechanism-using-TCP-muscles-for-applications/10.1117/12.2219535.full
- Biometic, lightweight, 3D printed hand with locking mechanism consisting of twisted and coiled polymer (TCP) muscles based on nylon precursor fibers as artificial muscles

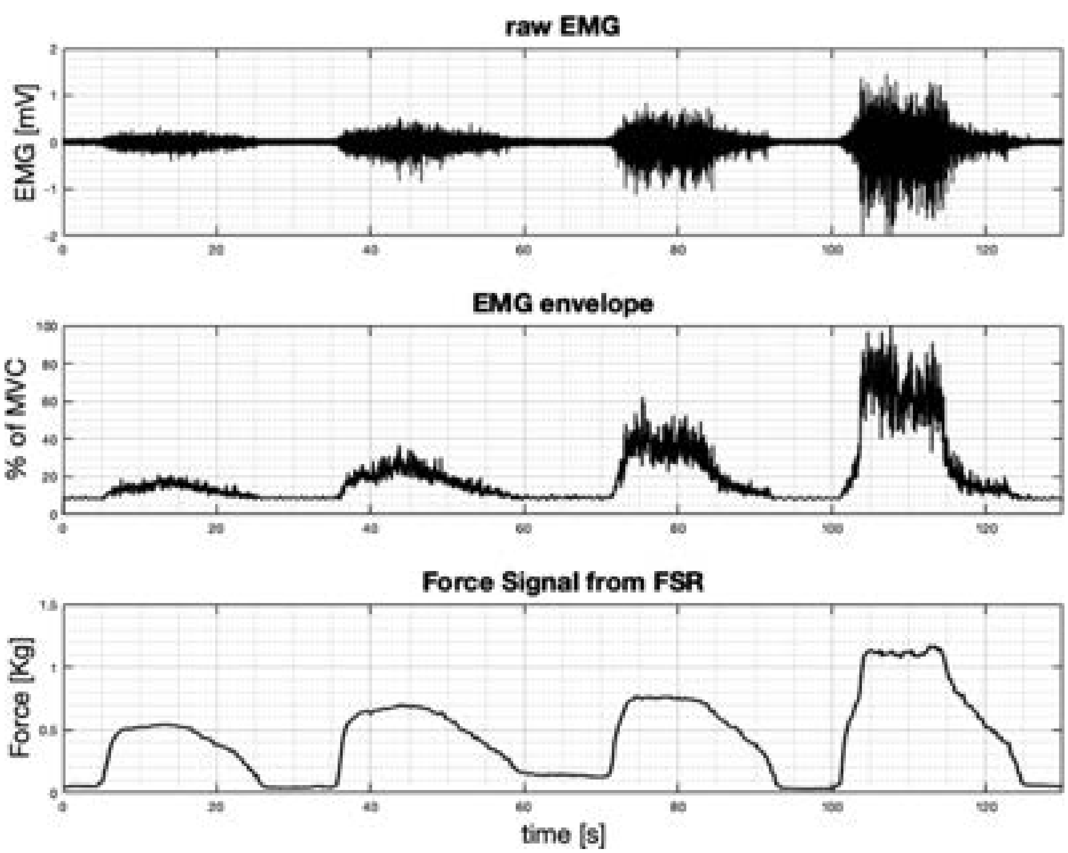
Experimental Study to Improve the "Federica" Prosthetic Hand



(a) (b)

https://link-springer-com.ezproxy.library.wisc.edu/chapter/10.1007/978-3-030-31635-8_70

- Only used 1 finger
- Used a Interlink FSR 402 sensor includes two membranes on which electrodes and conductive polymer are printed respectively
- Energy supplied with arduino board: powered with 5V
- Maximum weight tested with it was 2kg which is only around 5lbs



- Simultaneous recordings from flexor carpi ulnaris when performing four grasp actions at increasing strength: (a) Raw EMG signal; (b) EMG envelope; (c) FSR force signal (raw output).

Conclusions/action items:

These devices do not always have very good action time, however they do require less force output for the user than body powered designs. Unfortunetly the cost for myoelectric prosthetics is very high, and is not practical for many people.

Electronics Meeting

STEPHANIE SILIN - Dec 03, 2021, 6:29 PM CST

Title: Electronics Meeting with Professor Mark Allie

Date: 12/3

Content by: Stephanie

Present: Danielle and Stephanie

Goals: To get insight on our current circuit design

Content:

Questions:

- Can we power the arduino and the motor all from the same 2 7.5V batteries?

--> Yes we can, and we don't need a voltage divider, we can power the arduino (needs 6-12V) from the first battery then connect in series (parallel starts fires) and then power the motor off of the end of that, this way the arduino gets 7.5 and the motor gets 15V

----> we chould use smaller batteries and more of them though because that let's us get more current

------for example (https://www.instructables.com/How-to-use-a-Flex-Sensor-Arduino-Tutorial/)

- How do we know how long it will last?

---> We can measure from the amps and then calculate or just let it run and count lol

-----> he probably also wont be constantly moving thumb in and out so we can tell him "you get X amount of pinches per charge"

- How can we waterproof?

---> he laughed...

How can we get it smaller/portable?

---> find a nerd to help us, unfortunetly it may be hard to find someone who wants to build a circuit board with us, but we can hope

Conclusions/action items:

We need to find a way to make a circuit board, also we can get smaller batteries for more current so like 6 AAs or 3 3.7Vs, also rechargable is better because it has more current.

Solidworks Torque Motor

STEPHANIE SILIN - Oct 20, 2021, 2:05 PM CDT

Title: Solidworks torque motor

Date: 10/18/2021

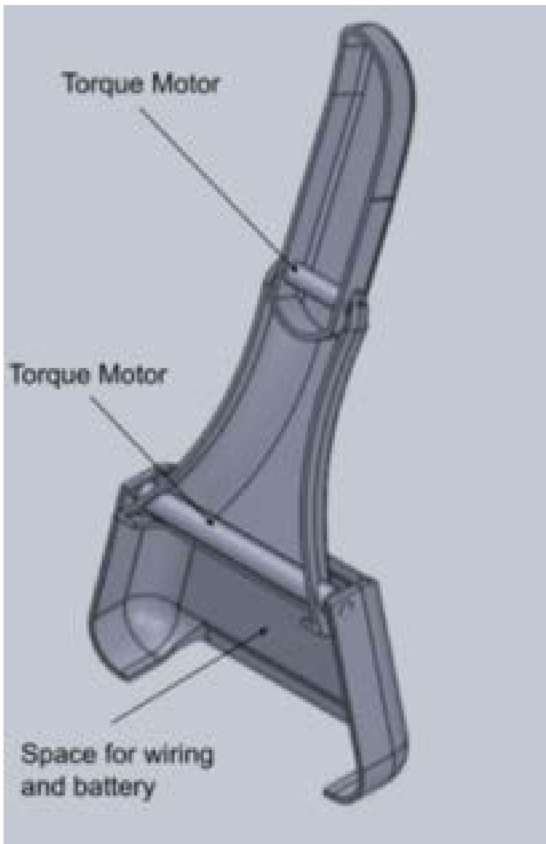
Content by: Stephanie Silin

Present: N/A

Goals: Model a torque version to have option if torque motors prove more force/space and cost than linear motors

Content:

see image



Conclusions/action items:

Do force calculations for linear and torque motors, potentially look at other motor types

STEPHANIE SILIN - Oct 20, 2021, 2:06 PM CDT

Torque_Model_Assembly_1.SLDASM(229 KB) - download

Motor Types

STEPHANIE SILIN - Oct 20, 2021, 2:13 PM CDT

Title: Motor Types

Date: 10/15/2021

Content by: Stephanie Silin

Present: N/A

Goals: Understand different types of motors that could be applicable for our design

Content:

https://aishack.in/tutorials/motors-youll-robotics/

DC Motors

- Rotational motion
- High speed
- High Torque
- Innaccurate
- Prone to burning out
- Do not immediately stop

Stepper Motors

- Rotational motion
- Very accurate
- Low torque
- Low speed
- Difficult to use

Servo Motors

- Linear motion
- Medium/High Accuracy
- High Torque
- Very expensive

Conclusions/action items:

It is not yet clear what the best option would be as the team is concerned with price, reaction time, and long-term use.

Code First Draw-Up

STEPHANIE SILIN - Dec 15, 2021, 1:52 PM CST

Title: Code First Draw Up

Date: 11/15

Content by: Stephanie

Present: Stephanie

Goals: To make the motor move

Content:

to see the circuit see the next entry

https://www.tutorialspoint.com/arduino/arduino_dc_motor.htm

From here I took this code:

```
int motorPin = 9;

void setup() {
   pinMode(motorPin, OUTPUT);
   Serial.begin(9600);
   while (! Serial);
   Serial.println("Speed 0 to 255");
}

void loop() {
   if (Serial.available()) {
      int speed = Serial.parseInt();
      if (speed >= 0 && speed <= 255) {
         analogWrite(motorPin, speed);
      }
   }
}
```

This, however, is causing me errors so this is what I ran to make it finally work:

```
void setup() {
  // initialize digital pin LED_BUILTIN as an output.
  pinMode(LED_BUILTIN, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
  digitalWrite(LED_BUILTIN, HIGH);
```

....yes this is basically the arduino basics blink code

Conclusions/action items:

The electronics need to be worked with on the flex sensor next before codes are combined/ code progresses much. So this code is good enough for now to prove the concept but will need to get much more complicated as this continues and the flex sensor is done then added to the design.

Electronics First Draw-Up

STEPHANIE SILIN - Dec 15, 2021, 1:48 PM CST

Title: Electronics First draw up

Date: 11/15

Content by: Stephanie Silin

Present: Stephanie

Goals: To get the linear motor to move

Content:

Taken from https://www.tutorialspoint.com/arduino/arduino_dc_motor.htm

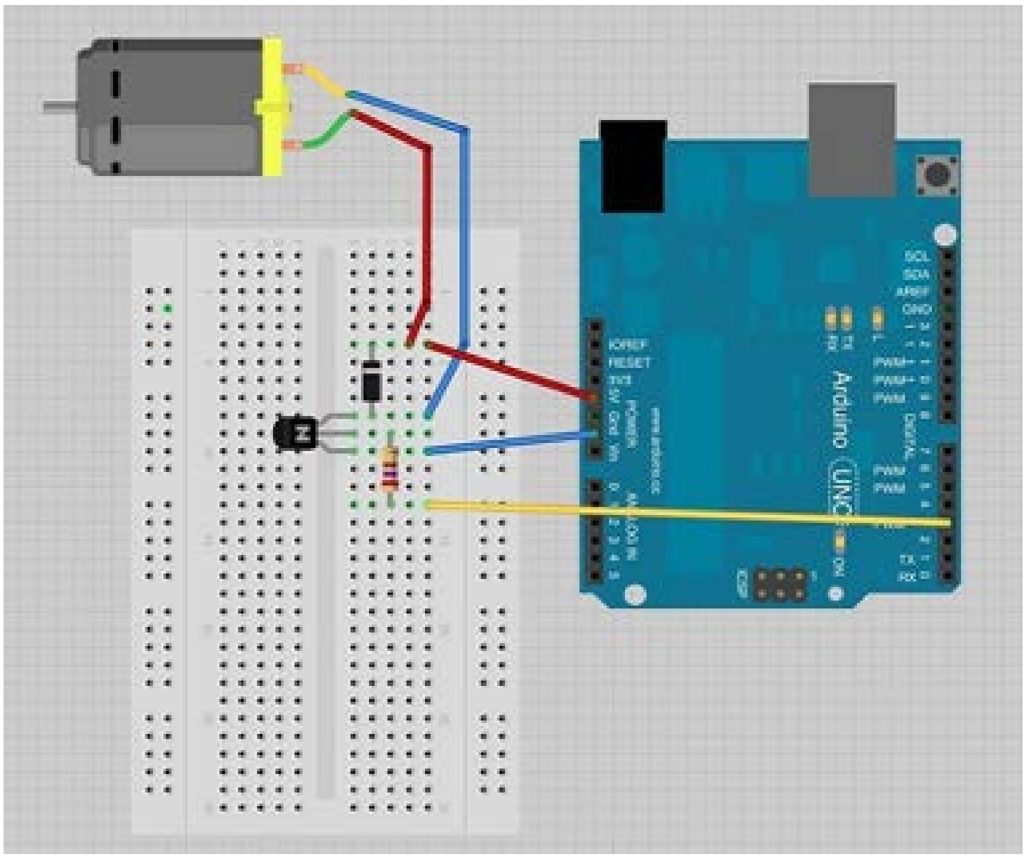
Components Required

You will need the following components −

- 1x Arduino UNO board
- 1x PN2222 Transistor
- 1x Small 6V DC Motor
- 1x 1N4001 diode
- 1x 270 Ω Resistor

Procedure

Follow the circuit diagram and make the connections as shown in the image given below.



What do I not have?

-diode: keeps current going all in 1 direction

-transistor: changes flow of current

If I just don't use the diode it's no biggie

If I skip the transistor I will need to manually switch the leads if I want the motor to go back in... this is fine I just want to make the motor move right now

My circuit:

see attachment it is the breadboard on the right, the other one was something else entirely.

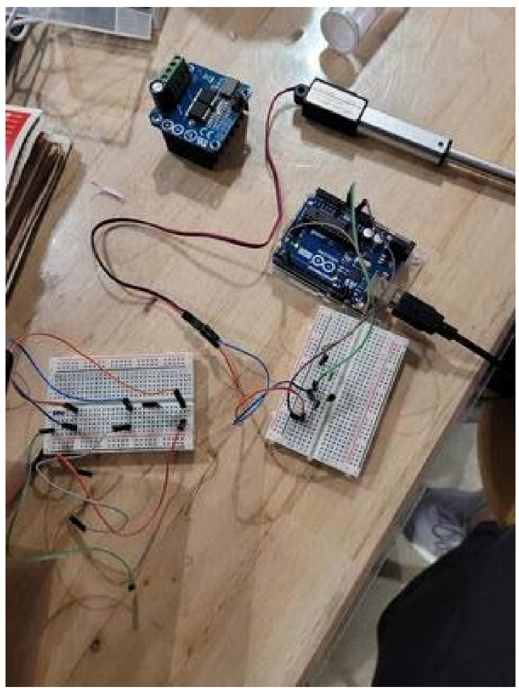
What happened?

This circuit did not work at first until I broke it (by that I mean disconnecting the lead I have lno clue what happened there), but then I reworked it and it was able to move (what you will see in attachment), I have to switch the leads if I want the motor to retract but as of right now I'm happy it is moving finally.

Conclusions/action items:

Currently this is not ideal, as this requires manual shifting, however getting the motor to move was good progress. Next I need to get the outputs of the flex sensor and also attach the motor to the motor driver so that way it can be programmed to switch on and off. I will likely work on this with Danielle as it is her expertise.

STEPHANIE SILIN - Dec 15, 2021, 1:44 PM CST



20211201_155301_1_.jpg(380.7 KB) - download

More Code and Electronics

STEPHANIE SILIN - Dec 15, 2021, 2:01 PM CST

Title: More code and electronics

Date: 11/30

Content by: Stephanie Silin

Present: Steph and Danielle

Goals: To get the flex sensor moving and start adding it to the motor

Content:

Content influenced by:

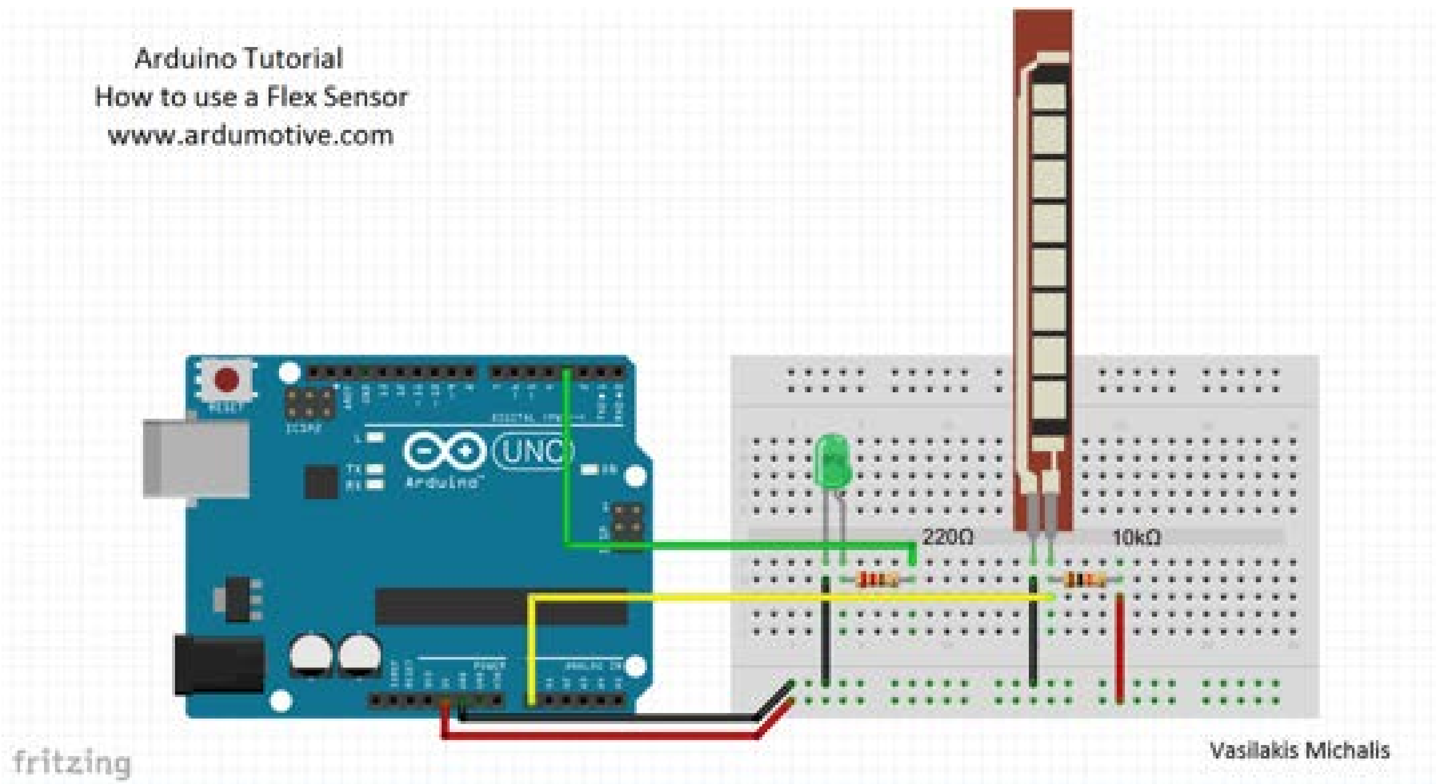
https://www.firgelliauto.com/blogs/tutorials/how-do-you-control-a-linear-actuator-with-an-arduino

https://www.instructables.com/How-to-use-a-Flex-Sensor-Arduino-Tutorial/

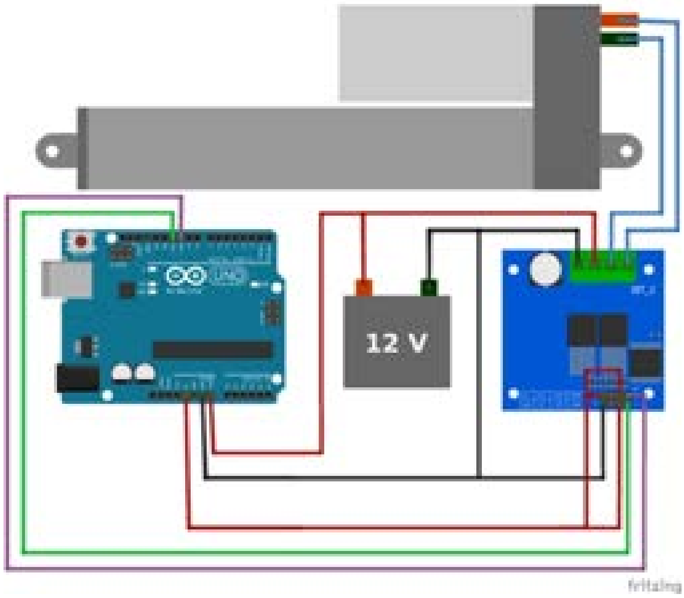
Flex senor tutorial we followed:

For this tutorial you will need:

- Arduino uno
- Breadboard
- Flex Sensor
- Led
- 10KOhm & 220 Ohm resistors



Linear Actuator Tutorial we followed:




```
byte Speed = 0; // Intialize Varaible for the speed of the motor (0-255);
int RPWM = 10;  //connect Arduino pin 10 to IBT-2 pin RPWM
int LPWM = 11;  //connect Arduino pin 11 to IBT-2 pin LPWM

void setup() {
pinMode(10, OUTPUT); // Configure pin 10 as an Output
pinMode(11, OUTPUT); // Configure pin 11 as an Output

}

void loop() {
  // Extend Actuator at Full Speed
  Speed = 255;
  analogWrite(RPWM, 0);
  analogWrite(LPWM, Speed);

  delay(2000); // 2 Seconds

  // Stop Actuator
  analogWrite(RPWM, 0);
  analogWrite(LPWM, 0);

  delay(2000); // 2 Seconds

  // Retract Actuator at Half Speed
  Speed = 127;
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);

  delay(2000); // 2 Seconds

  // Stop Actuator
  analogWrite(RPWM, 0);
  analogWrite(LPWM, 0);

  delay(2000); // 2 Seconds
```

Flex Sensor Code:

```
//Constants:
const int ledPin = 3;   //pin 3 has PWM funtion
const int flexPin = A0; //pin A0 to read analog input

//Variables:
int value; //save analog value
```

```
void setup(){

  pinMode(ledPin, OUTPUT);  //Set pin 3 as 'output'
  Serial.begin(57600);       //Begin serial communication

}

void loop(){

  value = analogRead(flexPin);         //Read and save analog value from potentiometer
  Serial.println(value);               //Print value
  value = map(value, 700, 900, 0, 255);//Map value 0-1023 to 0-255 (PWM)
  analogWrite(ledPin, value);          //Send PWM value to led
  delay(100);                          //Small delay
}
```

Flex Sensor Circuit:

see attachment

Together Code:

```
// the setup function runs once when you press reset or power the board
void setup() {
  Serial.begin(57600);

  // initialize digital pin LED_BUILTIN as an output.
  pinMode(13, OUTPUT);
  pinMode(12, OUTPUT);
  pinMode(11, OUTPUT);
  pinMode(A3, INPUT);
  pinMode(A4, INPUT);
  pinMode(A5, INPUT);
}

// the loop function runs over and over again forever
void loop() {

  int wrist = analogRead(A3);
  int arm = analogRead(A4);
  int foot = analogRead(A5);

  float wrist_volts = wrist * (5.0 / 1023.0);
  float arm_volts = arm * (5.0 / 1023.0);
  float foot_volts = foot * (5.0 / 1023.0);

  Serial.println(wrist_volts);
 // Serial.println(arm_volts);
 // Serial.println(foot_volts);

  if(wrist_volts >= 4) {
  digitalWrite(12, LOW);
  digitalWrite(11, LOW);
  digitalWrite(13, HIGH);   // turn the LED on (HIGH is the voltage level)
  // delay(1000);                       // wait for a second
  // digitalWrite(13, LOW);    // turn the LED off by making the voltage LOW
  // delay(1000);                       // wait for a second
  }
  else if(wrist_volts >= 2) {
  digitalWrite(11, LOW);
  digitalWrite(13, LOW);
```

```
digitalWrite(12, HIGH);   // turn the LED on (HIGH is the voltage level)
// delay(1000);                       // wait for a second
// digitalWrite(12, LOW);    // turn the LED off by making the voltage LOW
// delay(1000);
}

else {
digitalWrite(12, LOW);
digitalWrite(13, LOW);
digitalWrite(11, HIGH);   // turn the LED on (HIGH is the voltage level)
// delay(1000);                       // wait for a second
// digitalWrite(11, LOW);    // turn the LED off by making the voltage LOW
// delay(1000);

} }
```

Conclusions/action items:

We are having some issues determining if we can power this better, and how to waterproof it, also on runtime and we want some confirmation that we are doing alright here. Dan is setting up a meeting for us with one of her Professors for an electroncis class.

SolidWorks Explaination

STEPHANIE SILIN - Dec 15, 2021, 1:32 PM CST

Title: Solidworks Long L

Date: 12/5

Content by: Stephanie

Present: Stephanie

Goals: To adjust some of the existing components to see if the design works better

Content:

I reworked some of the existing pieces you will see in emily's folder

-- the parts that are part of this model that are not shown in my folder (as they are Emily's work) include: piston & cuff attachment

--the parts I reworked are: L, I, T --> since the T is used 2x in her design and I wanted them to be different I have 2 reworks for those

My motivation to change them is the design at this time does not work.

(note my design did not end up working either)

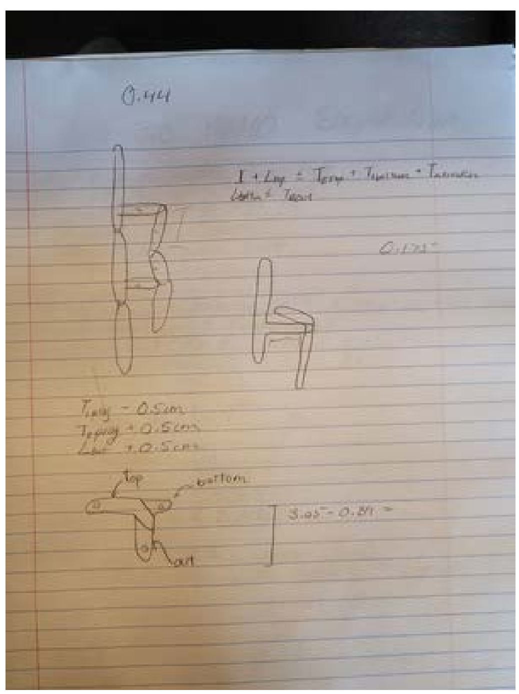
The idea for this design is that since the second phalynx and first phalynx joint supplying most of the motion was not moving at all that I could increase the length of the jutting out T joint (second T is design) and the length of the L joint, which could add more distance. The other part of this idea to have a better ROM is to shrink the jutting out bit of the first T joint. I also want it to move and I belive the problem is the I joint is not long enough and the bottom of T2 is not roatating since is has no room on the I joint.

see attachment for my rough drawings

Conclusions/action items:

Test this new model and see if it is an improvement and/or if it needs further improvement.

STEPHANIE SILIN - Dec 15, 2021, 1:32 PM CST



20211215_132758.jpg(2.6 MB) - download

Solidworks Long T

STEPHANIE SILIN - Dec 15, 2021, 1:21 PM CST

Title: Solidworks Long T

Date: 12/5

Content by: Stephanie

Present: Stephanie

Goals: To adjust some of the existing components to see if the design works better

Content:

See SolidWorks Explaination for detail

See attachment for part

Conclusions/action items:

Test this new model and see if it is an improvement and/or if it needs further improvement.

STEPHANIE SILIN - Dec 15, 2021, 1:22 PM CST

T_shape_long.STL(49.2 KB) - download

SolidWorks Short T

STEPHANIE SILIN - Dec 15, 2021, 1:21 PM CST

Title: Solidworks Short T

Date: 12/5

Content by: Stephanie

Present: Stephanie

Goals: To adjust some of the existing components to see if the design works better

Content:

See SolidWorks Explaination for detail

See attachment for part

Conclusions/action items:

Test this new model and see if it is an improvement and/or if it needs further improvement.

STEPHANIE SILIN - Dec 15, 2021, 1:21 PM CST

T_shape_short.STL(49.2 KB) - download

SolidWorks Long L

STEPHANIE SILIN - Dec 15, 2021, 1:19 PM CST

Title: Solidworks Long L

Date: 12/5

Content by: Stephanie

Present: Stephanie

Goals: To adjust some of the existing components to see if the design works better

Content:

See SolidWorks Explaination for detail

See attachment for part

Conclusions/action items:

Test this new model and see if it is an improvement and/or if it needs further improvement.

STEPHANIE SILIN - Dec 15, 2021, 1:20 PM CST

L_shape_long.STL(52.3 KB) - download

Solidworks Long I

STEPHANIE SILIN - Dec 15, 2021, 1:22 PM CST

Title: Solidworks Long I

Date: 12/5

Content by: Stephanie

Present: Stephanie

Goals: To adjust some of the existing components to see if the design works better

Content:

See SolidWorks Explaination for detail

See attachment for part

Conclusions/action items:

Test this new model and see if it is an improvement and/or if it needs further improvement.

STEPHANIE SILIN - Dec 15, 2021, 1:23 PM CST

I_shape_long.STL(36.1 KB) - download

Flex-Seal Application

STEPHANIE SILIN - Dec 15, 2021, 1:17 PM CST

Title: Flex Seal Application

Date: 11/30

Content by: Stephanie Silin

Present: Stephanie

Goals: To obtain more friction on the surface of the thumb

Content:

As mentioned in my research notes: the fingerprint offers an increase in friction of the hand. This allows us to pick this up and grip better, and is largely related to the ridges in the finger. My goal here was to test 2 different methods of 'texturizing' the flex seal coating.

Method 1:

Apply with a cloth

(see top of stick in attached image)

Method 2:

Dip in flex seal then dab with cloth

(see bottom of stick in attached image)

Method 2 ended up working better, it gave a thicker coating and felt like it had deeper ridges than method 2.

Conclusions/action items:

Implement the working method 2 this on the final design

STEPHANIE SILIN - Dec 15, 2021, 1:17 PM CST

20211203_141003.jpg(3.6 MB) - download

Sleeve Sewing

STEPHANIE SILIN - Dec 15, 2021, 1:12 PM CST

Title: Sleeve Sewing

Date: 12/2/2021

Content by: Stephanie

Present: Stephanie

Goals: Sew a sleeve for padding the cuff and to keep the flex sensor in place

Content:

Found a sweatshirt in the free materials at makerspace, cut off the sleeve, hemmed it and then attached a small pocket on the inside 1.5" by 4.5" with the opening facing the elbow. This fit the sensor but when the sleeve is worn the motor goes crazy, so either this or the motor needs to be adjusted.

I had also attempted with a different arm pad but it was very loose and made of a wolven material so I couldn't really adjust the size without it falling apart, and this should be a more 'tidy' design.

Conclusions/action items:

The flex sensor is too sensitive for this to be worn on the wrist without causing the motor to be continuously triggered. The code needs to be updated to accomate this.

Final Circuitry Design

STEPHANIE SILIN - Dec 15, 2021, 1:03 PM CST

Title: Current Circuitry Model

Date: 12/1/2020

Content by: Stephanie and Danielle

Present: Stephanie and Danielle

Goals: Create the last design to be displayed at the Final Presentation

Content:

Flex Sensor code:

```
//Constants:
const int ledPin = 3;   //pin 3 has PWM funtion
const int flexPin = A0; //pin A0 to read analog input

//Variables:
int value; //save analog value


void setup(){

  pinMode(ledPin, OUTPUT);  //Set pin 3 as 'output'
  Serial.begin(57600);       //Begin serial communication

}

void loop(){

  value = analogRead(flexPin);         //Read and save analog value from potentiometer
  Serial.println(value);               //Print value
  value = map(value, 700, 900, 0, 255);//Map value 0-1023 to 0-255 (PWM)
  analogWrite(ledPin, value);          //Send PWM value to led
  delay(100);                          //Small delay
}
```

Motor Code:

```
byte Speed = 0; // Intialize Varaible for the speed of the motor (0-255);
int RPWM = 10;  //connect Arduino pin 10 to IBT-2 pin RPWM
int LPWM = 11;  //connect Arduino pin 11 to IBT-2 pin LPWM

void setup() {
pinMode(10, OUTPUT); // Configure pin 10 as an Output
pinMode(11, OUTPUT); // Configure pin 11 as an Output

// start at full retraction of motor
  Speed = 255;
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);

  delay (7500);
}

void loop() {


  // Extend Actuator at Full Speed
  Speed = 255;
```

```
  analogWrite(RPWM, 0);
  analogWrite(LPWM, Speed);

  delay(7500); // 10 Seconds

  // Stop Actuator
  //analogWrite(RPWM, 0);
  //analogWrite(LPWM, 0);

  //delay(6000); // 10 Seconds

  // Retract Actuator at Half Speed
  Speed = 255;
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);

  delay(7500); // 10 Seconds

  // Stop Actuator
  //analogWrite(RPWM, 0);
  //analogWrite(LPWM, 0);

  //delay(10000); // 10 Seconds
}
```

Final Code:

```
//Constants:
const int ledPin = 3;   //pin 3 has PWM funtion
const int flexPin = A0; //pin A0 to read analog input

//Variables:
int value; // convert analog value to scale of 0-5
int flexValue; //save analog value
int oldValue; // marker to stop movement of motor when necessary

byte Speed = 255; // Intialize Varaible for the speed of the motor (0-255);
int RPWM = 10;  //connect Arduino pin 10 to IBT-2 pin RPWM
int LPWM = 11;  //connect Arduino pin 11 to IBT-2 pin LPWM
bool caught = false; // ensures that after the loop goes around once it doesn't continue to extend after it has already extended


void setup(){

  pinMode(ledPin, OUTPUT);  //Set pin 3 as 'output'
  Serial.begin(74880);   //Begin serial communication
  pinMode(10, OUTPUT); // Configure pin 10 as an Output
  pinMode(11, OUTPUT); // Configure pin 11 as an Output

// start at full retraction of motor for baseline
  //Speed = 255;
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);

  delay (7500); // max length = 7.5 seconds

  oldValue = 0; // initialize value for comparison

}

void loop(){

  flexValue = analogRead(flexPin);         //Read and save analog value from potentiometer
  value = flexValue * (5.0 / 1023.0);  // convert to a scale of 0-5
  Serial.println(value);               //Print value

  if(value != oldValue) {    // if value does equal old value, this means no change has been made by user
                           // and desire is to maintain that amount of flexion
```

```
  if(value <= 2 && !caught) { // full flexion of wrist = full bend in thumb desired
  // Extend Actuator at Full Speed
  analogWrite(RPWM, 0);
  analogWrite(LPWM, Speed);

  delay(2000); // 2 Seconds
  caught = true; // establishes that it has already gone through and extended once
  }

  //else if(value <= 4) {     // partial flexion of the wrist = partial bend in thumb
// Retract Actuator to halfway // possible addition for second semester
  //analogWrite(RPWM, Speed);
  //analogWrite(LPWM, 0);

  //delay(3750); // 3.75 Seconds
 // }

  else {
// Retract Actuator fully
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);
  caught = false;

  delay(2000); // 2 Seconds

  }

  // Stop Actuator
  analogWrite(RPWM, 0);
  analogWrite(LPWM, 0);

}
oldValue = value;
}
```

Final Design:

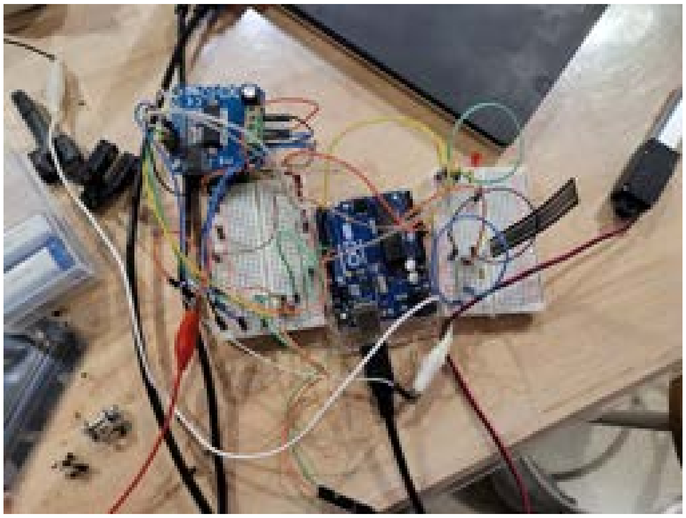
See Attachments

I also hooked up the arduino to be powered from the first battery in the series, not shown in images, but the design is the same.

Conclusions/action items:

This design function when the sleeve was not being worn, however it is not very moble and the it is difficult to wear. The code needs to be adjusted so it is less sensistive (when you wear the sleeve the motor repeatedly goes in and out). Additionally it needs to be substantially taken down in size and made more wearable for the wrist.

STEPHANIE SILIN - Dec 15, 2021, 1:04 PM CST



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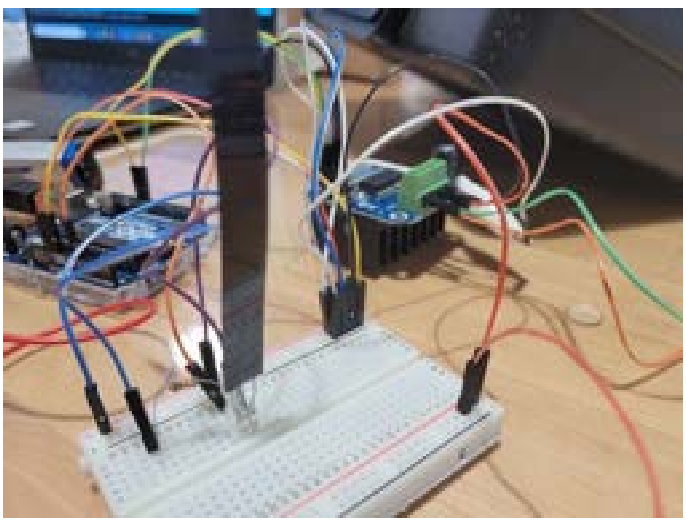
STEPHANIE SILIN - Dec 15, 2021, 1:04 PM CST

20211202_174549.mp4(5.8 MB) - download

STEPHANIE SILIN - Dec 15, 2021, 1:04 PM CST



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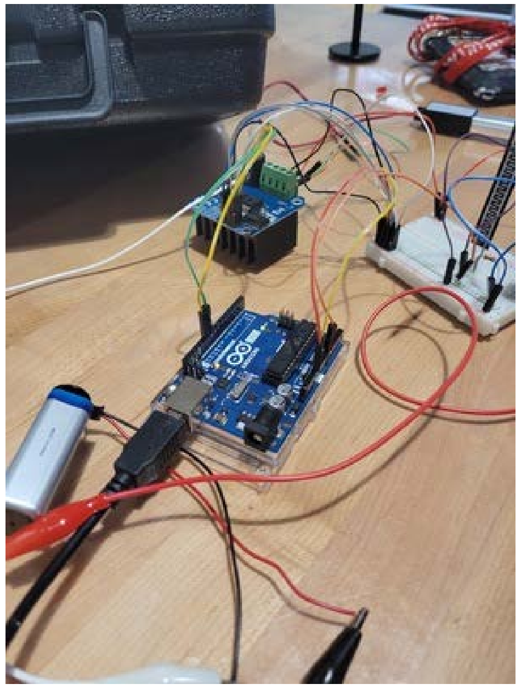
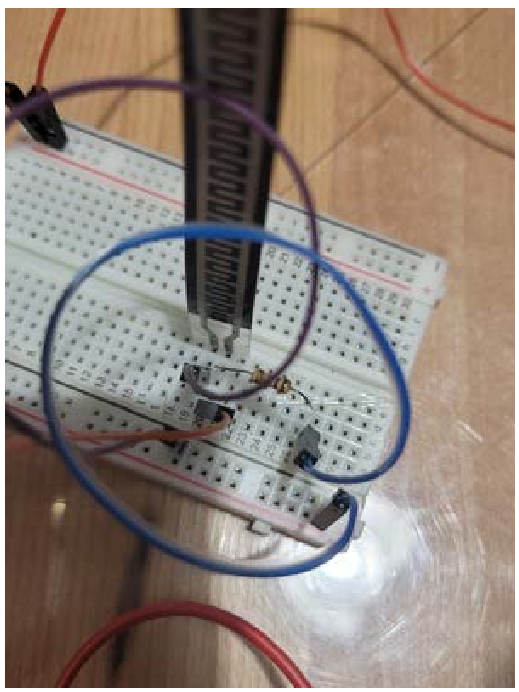
STEPHANIE SILIN - Dec 15, 2021, 1:04 PM CST



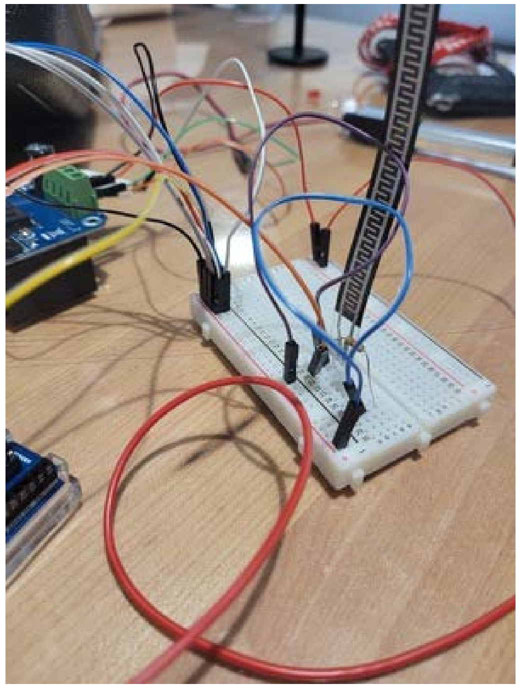
20211203_145356.jpg(3.3 MB) - download

STEPHANIE SILIN - Dec 15, 2021, 1:04 PM CST



20211203_145408.jpg(2.2 MB) - download

STEPHANIE SILIN - Dec 15, 2021, 1:04 PM CST



20211203_145344.jpg(3.2 MB) - download

Red Pass and Laser Permit

STEPHANIE SILIN - Oct 06, 2020, 8:20 PM CDT

Title: Red Page

Date: 10/6/2020

Content by: Stephanie Silin

Present: Stephanie Silin

Goals: Prove documentation of Red Pass and Laser Permit

Content:

See attachment of Red Pass and Laser Permit

Conclusions/action items:

N/A

STEPHANIE SILIN - Oct 06, 2020, 8:22 PM CDT

redpermitdocumentation.png(49.9 KB) - download

9/16/2021 - Size and weight of human and prosthetic hand

DANIELLE LEFKO - Dec 13, 2021, 8:24 PM CST

Title: Size and weight of human and prosthetic hand

Date: 9/16/2021

Content by: Danielle Lefko

Present: Danielle

Goals: to determine the size and weight of a human and prosthetic hand for the PDS

Content:

https://www.eng.yale.edu/grablab/pubs/Belter_ICORR2011.pdf

J. T. Belter and A. M. Dollar, “Performance characteristics of anthropomorphic prosthetic hands,” *2011 IEEE International Conference on Rehabilitation Robotics*, 2011.

- human hand weighs about 400g
    - "distal to the wrist and not including the forearm extrinsic muscles"
- users have indicated that prosthetics of similar weight are too heavy
    - as a result of attachment
- Biddiss found that people valued the weight of the prosthetic as 70%
- current options are between 113g to 615g as seen in current commercial prosthetics
    - 350g to 2200g in research based hands

Table I: General Characteristics of Five Current Prosthetic Hands

	Developers	Number of Joints	Degrees of Freedom	Number of Actuators	Actuation Method	Joint Coupling Method	Adaptive grip	Overall Size	Weight
Hosmer Hook [7,8]	Hosmer Corp.	1	1	1	Body Powered	-	No	124 mm long	113-312 grams
SensorHand [9,10]	Ottobock inc.	2	1	1	DC Motor	Fixed pinch	No	Fits inside glove	350-500 grams
Becker Hand (1968) [11,8]	Becker Mechanical Hands Inc.	5	5	1	Body Powered	Spring fingers (act like trunk)	Yes	143 mm long	382-467 grams
i-Limb (2009) [12,13]	Touch Bionics	11	11	5	DC Motors	Tendon Linking MP to PIP	Yes	180-182 mm long, 80-75 mm wide, 35-41 mm thick	450-615 grams
Bebionic (2011) [14]	RSL Steeper	11	11	5	DC Motors	links spanning MP to PIP	Yes	198 mm long, 90 mm wide	495-539 grams

(-) Data not applicable to hand

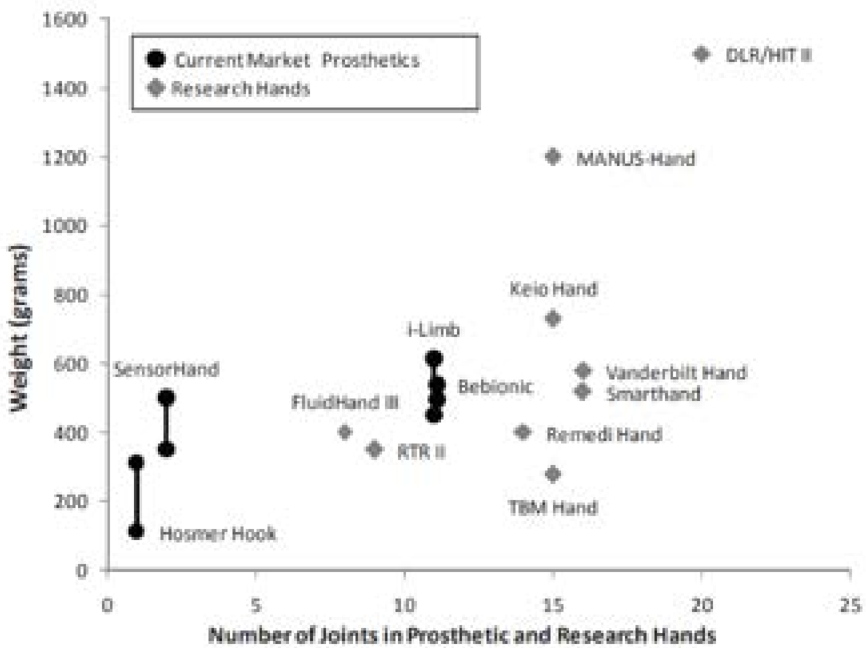


Fig. 1: Distribution of the weights of prosthetic and research hands plotted against the number of joints in each hand.

- these figures show current prosthetic hands' weights
  - there is no specific max weight required
    - dependent on size and function of prosthetic
- while it is debated amongst different members of the prosthetic development community, average consensus is that an adult prosthetic hands should weigh less than 400g

Conclusions/action items:

The total prosthetic device should remain below 400 grams. The next steps will be to look into what complications are common to occur after amputations.

10/14/2021 - Complications post amputation

DANIELLE LEFKO - Dec 13, 2021, 8:25 PM CST

Title: Complications Post Amputation

Date: 10/14/2021

Content by: Danielle

Present: Danielle

Goals: to research possible complications after an amputation

Content:

https://www.physio-pedia.com/Complications_Post_Amputation

> “Complications post amputation,” *Physiopedia*. [Online]. Available: https://www.physio-pedia.com/Complications_Post_Amputation. [Accessed: 19-Oct-2021].

- oedema
  - can result in wound breakdown, pain, reduced mobility, difficulties with prosthetic fitting
- skin blisters
  - can be caused by oedema, reduced elasticity, tight stump dressings, infection, traction, and allergic reaction
- pain
  - can occur as neuromas
    - localized pain, sharp/shooting paraesthesia
- muscle weakness and joint instability

Conclusions/action items:

These complications are things to look out for with our patient when thinking about designing a prosthetic for him. The next steps will be to look into grip force of hands to be able to replicate the necessary requirements in our design.

10/19/2021 - grip force exploration

DANIELLE LEFKO - Dec 13, 2021, 8:25 PM CST

Title: Grip Force Exploration

Date: 10/19/2021

Content by: Danielle

Present: Danielle

Goals: to understand the grip force regulation of low impedance myoelectric prosthesis

Content:

https://pubmed.ncbi.nlm.nih.gov/26602538/

> Brown JD;Paek A;Syed M;O'Malley MK;Shewokis PA;Contreras-Vidal JL;Davis AJ;Gillespie RB; “An exploration of grip force regulation with a low-impedance myoelectric prosthesis featuring referred haptic feedback,” *Journal of neuroengineering and rehabilitation*. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/26602538/. [Accessed: 20-Oct-2021].

- referred haptic feedback is not advanced enough to simulate a natural limb's reflexes when adjusting for different object weights
  - this makes this an impractical solution for an additional feature to the bionic design

Conclusions/action items:

It will not be helpful to look further into referred haptic feedback. This is an area that is not explored enough and will not be a beneficial solution for this project. I will need to continue looking into grip force of the hand in other sources.

10/19/2021 - scaling of grip force

DANIELLE LEFKO - Dec 13, 2021, 8:26 PM CST

Title: Scaling of grip force

Date: 10/19/2021

Content by: Danielle

Present: Danielle

Goals: to look further into how the body responds in anticipation of what grip force is necessary when picking up objects

Content:

https://pubmed.ncbi.nlm.nih.gov/21541765/

> Hermsdörfer J;Li Y;Randerath J;Goldenberg G;Eidenmüller S; "Anticipatory scaling of grip forces when lifting objects of everyday life," *Experimental brain research*. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/21541765/. [Accessed: 20-Oct-2021].

- a study was conducted with 11 participants
  - they were given objects from daily life ranging with different weights
  - the grip force was measured through sensors on the finger tips
  - the control group was unable to recognize the object prior to picking it up
  - they found that object weight was accurately anticipated through scaled grip force

Conclusions/action items:

The ability of the human body to scale grip force will likely play a role in the effectiveness of the prosthetic. The prosthetic will either need to be able to reproduce this function (much more complex), or there will be a learning curve when first utilizing the prosthetic device. The latter is the more likely outcome. The next step is to look into different design ideas for the prosthetic using this information.

9/17/2021 - bebionic design

DANIELLE LEFKO - Dec 13, 2021, 8:27 PM CST

Title: Bebionic Design

Date: 9/17/2021

Content by: Danielle

Present: Danielle

Goals: to learn about bebionic prosthetic designs

Content:

https://www.ottobockus.com/prosthetics/upper-limb-prosthetics/solution-overview/bebionic-hand/#video-2

> “Bebionic hand,” *ottobock.* [Online]. Available: https://www.ottobockus.com/prosthetics/upper-limb-prosthetics/solution-overview/bebionic-hand/#video-2. [Accessed: 19-Oct-2021].

- 14 grip patterns and hand positions
- individual motors in each finger
- intended for individuals with all levels at or above the wrist

Conclusions/action items:

This design has valuable elements that enhance their functions, however, it is not a suitable option for our client due to his remaining palm and fingers. This can be a good reference to utilize for future designs. The next step is to look into other competing designs to collect a bigger picture.

9/17/2021 - arm dynamics designs

DANIELLE LEFKO - Dec 13, 2021, 8:27 PM CST

Title: Air Dynamics Designs

Date: 9/17/2021

Content by: Danielle

Present: Danielle

Goals: to learn about the air dynamics designs

Content:

https://www.armdynamics.com/our-care/finger-and-partial-hand-prosthetic-options

A. Dynamics, “Finger and partial hand prosthetic options,” *Arm Dynamics*. [Online]. Available: https://www.armdynamics.com/our-care/finger-and-partial-hand-prosthetic-options. [Accessed: 19-Oct-2021].

- the hybrid partial hand prosthesis seems like a good option for our client
    - combining elements of the electrically powered prosthesis and the activity specific prosthesis could be useful for the patient because he needs to be able to go back to work

Conclusions/action items:

Our client would greatly benefit from a combination of an electrically powered and a task specific prosthesis. Our client needs to be able to work on an assembly line so adding in that extra feature would be helpful. The next step is to continue adding more competing ideas to understand what options are on the market.

9/17/2021 - U of Michigan prosthetic design

DANIELLE LEFKO - Dec 13, 2021, 8:28 PM CST

Title: U of Michigan prosthetic design

Date: 9/17/2021

Content by: Danielle

Present: Danielle

Goals: to learn more about the U of Michigan's prosthetic design

Content:

https://labblog.uofmhealth.org/health-tech/its-like-you-have-a-hand-again

N. C. Moore, “'it's like you have a hand again',” *University of Michigan*, 04-Mar-2020. [Online]. Available: https://labblog.uofmhealth.org/health-tech/its-like-you-have-a-hand-again. [Accessed: 19-Oct-2021].

- this design utilizes electrode sensors to make the prosthetic move
    - allows for individual motor control
- nerve signals in the arm are small
    - they were able to make a breakthrough
        - "In previous approaches, you might get 5 microvolts or 50 microvolts - very, very small signals. We've seen the first ever millivolt signals."

Conclusions/action items:

It might be difficult to use the nerve signals in the arm to make the prosthetic move. The next step is to find one more example of another design to compare when discussing ideas for our design.

9/20/2021 - e-Nable competing design

DANIELLE LEFKO - Dec 13, 2021, 8:29 PM CST

Title: e-Nable competing design

Date: 9/20/2021

Content by: Danielle

Present: Danielle

Goals: to demonstrate a preexisting cost effective design

Content:

https://enablingthefuture.org/

“Enabling the future,” *Enabling The Future*. [Online]. Available: https://enablingthefuture.org/. [Accessed: 19-Oct-2021].

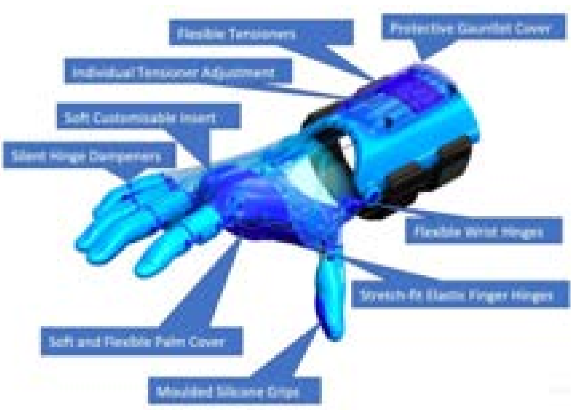


Figure above: model on the e-Nable website

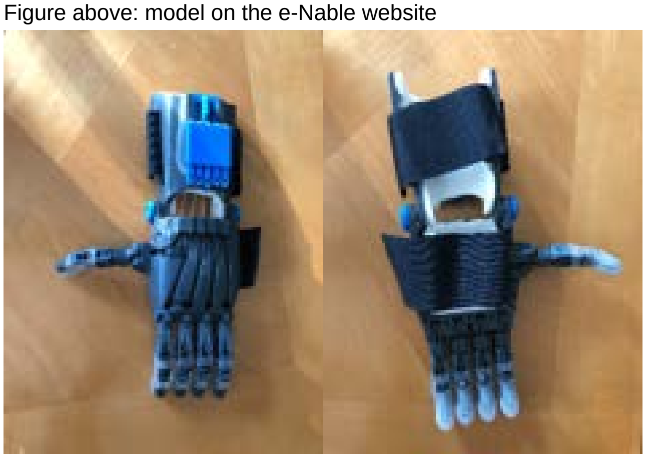


Figure above: device donated to me about 6 years ago

Conclusions/action items:

This is a good reference when determining what design would function best for the patient. The donated device is also a good source for materials or parts if necessary as it is no cost. The next step is to look into design ideas now that we have information about the function of the hand and amputations and ideas on what other designs are on the market.

10/27/21 - powering arduino with battery

DANIELLE LEFKO - Dec 13, 2021, 8:33 PM CST

Title: Powering arduino with battery

Date: 10/27/21

Content by: Danielle

Present: everyone

Goals: to determine how to power the arduino without using a computer to make it portable

Content:

https://www.instructables.com/Powering-Arduino-with-a-Battery/

> Amandaghassaei and Instructables, “Powering Arduino with a battery,” *Instructables*, 28-Oct-2017. [Online]. Available: https://www.instructables.com/Powering-Arduino-with-a-Battery/. [Accessed: 14-Dec-2021].

- arduino is operation with 6 - 20 V externally
    - less than 7V externally results in possibly less voltage from the 5V pin
    - recommend 7-12V
        - we could use 9V

Conclusions/action items:

It is possible to power the arduino with 9V from batteries. The next step is to determine the appropriate type and number of batteries to power both the arduino and the linear actuator.

12/3/2021 - Meeting with Professor Mark Allie about circuitry

DANIELLE LEFKO - Dec 13, 2021, 8:34 PM CST

Title: Meeting with Professor Mark Allie about circuitry

Date: 12/3/2021

Content by: Danielle

Present: Danielle and Stephanie

Goals: to learn about how to improve the circuitry design

Content:

- 9V batteries might not be enough to maintain enough power for an extended period of time because they don't have enough current
- possible solution options would be AAA batteries (unsure how many at the moment) 6 AA batteries in series or 3 3.7V lithium ion batteries
    - lithium ion batteries are a good choice because they provide more current but there isn't a connector cap for them at the makerspace for easy removal of the batteries to recharge
        - could search the internet for one

Conclusions/action items:

We must measure how many strokes from the linear actuator the batteries can handle before a recharge is necessary => aka how long the prosthetic can be used for. If the batteries aren't enough for 10 hours of use, a new battery option must be pursued. The next steps will be to complete this measurement and determine if the prosthetic can perform for 10 hours of use. If this is not the case, we will then determine what batteries can be used to allow for optimal performance for 10 hours.

10/3/2021 - Claw Design idea

DANIELLE LEFKO - Dec 13, 2021, 8:35 PM CST

Title: Claw Design Idea

Date: 10/3/2021

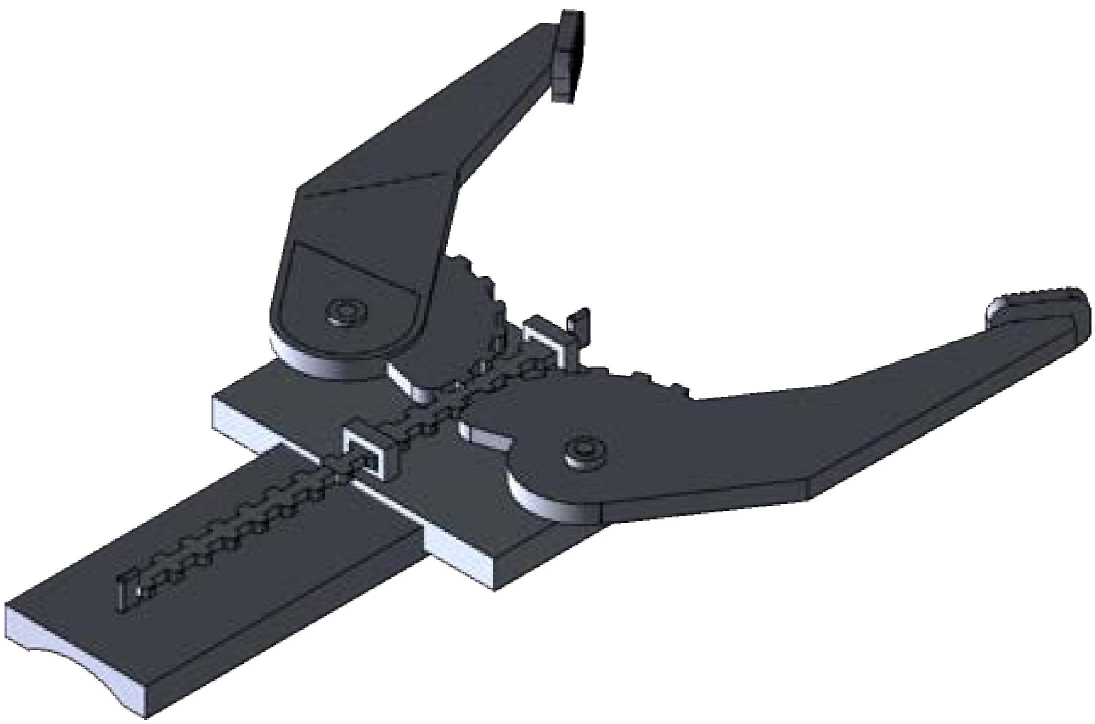
Content by: Danielle

Present: Danielle

Goals: To record our design ideas

Content:

- after meeting with the client, it is clear that 2/3 of the patient's forearm is affected and there is sensitivity in the areas of amputation of his fingers
- I think that a single mechanical thumb can be attached and controlled through electrode sensors that read signals from the top of his forearm where there are no grafts
    - this thumb would be modeled after half of a claw design
    - the remaining functional pinky finger would act in opposition as the other half of the claw



https://grabcad.com/library/mechanical-claw-5

"Free CAD designs, Files & 3D models: The grabcad community library," *Free CAD Designs, Files & 3D Models | The GrabCAD Community Library*. [Online]. Available: https://grabcad.com/library/mechanical-claw-5. [Accessed: 19-Oct-2021].

Conclusions/action items:

This model is a good place to start when coming up with a design moving forward. The next step will be to look into a sensor that can be used on the patients arm to read muscle activity of the forearm.

10/3/2021 - muscle sensor incorporation

DANIELLE LEFKO - Dec 13, 2021, 8:36 PM CST

Title: Muscle Sensor Incorporation

Date: 10/3/2021

Content by: Danielle

Present: Danielle

Goals: to learn more about types of EMG Sensors to be included in the design that reads muscle movements

Content:

https://www.biometricsltd.com/surface-emg-sensor.htm

> "Surface EMG sensor," *Surface EMG Muscle Sensor | Biometrics Ltd*. [Online]. Available: https://www.biometricsltd.com/surface-emg-sensor.htm. [Accessed: 20-Oct-2021].
>
> Surface EMG Sensor

- amplifier input impedance is >100 MOhms
  - this is good because it means there is no skin prep that needs to be done before using the sensor
  - can be wireless

Conclusions/action items:

This would be beneficial for the client to have a wireless sensor option to be applied further up on the arm where there are no skin grafts. The next step is to look into a motor that would function to flex the thumb and be portable.

10/27/21 - Possible linear actuator arduino code

DANIELLE LEFKO - Dec 13, 2021, 8:40 PM CST

Title: Possible linear actuator arduino code

Date: 10/27/21

Content by: Danielle

Present: everyone

Goals:

Content:

https://www.firgelliauto.com/blogs/tutorials/how-do-you-control-a-linear-actuator-with-an-arduino

> F. A. Team, “How do you control a linear actuator with an Arduino?,” *Firgelli Automations*, 29-May-2020. [Online]. Available: https://www.firgelliauto.com/blogs/tutorials/how-do-you-control-a-linear-actuator-with-an-arduino. [Accessed: 14-Dec-2021].

- a linear actuator is a good motor to use with the arduino
    - the arduino has good control over this motor
- this is also a good source to look at when beginning the creation of the circuitry and code

Conclusions/action items:

This is a good reference to look back on in the future. The next step is to begin brainstorming an outline for the general idea of the code that filters information from an input and results in a specific output. This will be used as a general outline for demonstrative purposes during show and tell.

11/2/21 - sample circuitry and code for show and tell

DANIELLE LEFKO - Dec 03, 2021, 6:21 PM CST

Title: Sample circuitry and code for show and tell

Date: 11/2/21

Content by: Danielle

Present: Danielle and Stephanie

Goals: to create a circuitry and code sample that can demonstrate the idea for future code to peers at show and tell

Content:

```
*/

// the setup function runs once when you press reset or power the board
void setup() {
  Serial.begin(57600);

  // initialize digital pin LED_BUILTIN as an output.
  pinMode(13, OUTPUT);
  pinMode(12, OUTPUT);
  pinMode(11, OUTPUT);
  pinMode(A3, INPUT);
  pinMode(A4, INPUT);
  pinMode(A5, INPUT);
}

// the loop function runs over and over again forever
void loop() {

  int wrist = analogRead(A3);
  int arm = analogRead(A4);
  int foot = analogRead(A5);

  float wrist_volts = wrist * (5.0 / 1023.0);
  float arm_volts = arm * (5.0 / 1023.0);
  float foot_volts = foot * (5.0 / 1023.0);

  Serial.println(wrist_volts);
 // Serial.println(arm_volts);
```

```
// Serial.println(foot_volts);


if(wrist_volts >= 4) {
digitalWrite(12, LOW);
digitalWrite(11, LOW);
digitalWrite(13, HIGH);   // turn the LED on (HIGH is the voltage level)
// delay(1000);                       // wait for a second
// digitalWrite(13, LOW);    // turn the LED off by making the voltage LOW
// delay(1000);                       // wait for a second
}
else if(wrist_volts >= 2) {
digitalWrite(11, LOW);
digitalWrite(13, LOW);
digitalWrite(12, HIGH);   // turn the LED on (HIGH is the voltage level)
// delay(1000);                       // wait for a second
// digitalWrite(12, LOW);    // turn the LED off by making the voltage LOW
// delay(1000);
}


else {
digitalWrite(12, LOW);
digitalWrite(13, LOW);
digitalWrite(11, HIGH);   // turn the LED on (HIGH is the voltage level)
// delay(1000);                       // wait for a second
// digitalWrite(11, LOW);    // turn the LED off by making the voltage LOW
// delay(1000);
} }
```

The electrode sensors input a value, filter it through the if statements, then turn different LED lights on; yellow, orange, and red. Red indicates the highest degree of signal from the muscle and yellow indicates a relaxed muscle.

Conclusions/action items:

This code was able to demonstrate the ability to take an input from a sensor and filter it through different categories to get a desired output response. The next steps will be to apply this once the linear actuator and flex sensor arrive.

12/1/2021 - test code for linear actuator

DANIELLE LEFKO - Dec 03, 2021, 6:35 PM CST

Title: Test code for linear actuator

Date: 12/1/2021

Content by: Danielle

Present: Danielle and Stephanie

Goals: to write code that tests if the linear actuator works

Content:

the following code was sourced from https://www.firgelliauto.com/blogs/tutorials/how-do-you-control-a-linear-actuator-with-an-arduino and adjustments were made as necessary

```
byte Speed = 0; // Intialize Varaible for the speed of the motor (0-255);

int RPWM = 10;  //connect Arduino pin 10 to IBT-2 pin RPWM

int LPWM = 11;  //connect Arduino pin 11 to IBT-2 pin LPWM


void setup() {

pinMode(10, OUTPUT); // Configure pin 10 as an Output

pinMode(11, OUTPUT); // Configure pin 11 as an Output


// start at full retraction of motor for baseline

  Speed = 255;

  analogWrite(RPWM, Speed);

  analogWrite(LPWM, 0);


  delay (7500); // max length = 7.5 seconds

}


void loop() {




  // Extend Actuator at Full Speed

  Speed = 255;

  analogWrite(RPWM, 0);

  analogWrite(LPWM, Speed);


  delay(7500); // 7.5 Seconds
```

```
  // Stop Actuator
  //analogWrite(RPWM, 0);
  //analogWrite(LPWM, 0);

  //delay(6000); // 7.5 Seconds

  // Retract Actuator at Full Speed
  Speed = 255;
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);

  delay(7500); // 7.5 Seconds

  // Stop Actuator
  //analogWrite(RPWM, 0);
  //analogWrite(LPWM, 0);

  //delay(10000); // 10 Seconds
}
```

Conclusions/action items:

Now that the linear actuator has been tested and is running appropriately, this code will need to be modified to work with the flex sensor in the final code. That will be worked on tomorrow.

12/1/2021 - test code for flex sensor

DANIELLE LEFKO - Dec 03, 2021, 6:38 PM CST

Title: Test code for flex sensor

Date: 12/1/2021

Content by: Danielle

Present: Danielle and Stephanie

Goals: to write code that tests if the flex sensor works

Content:

the following code was sourced from https://www.instructables.com/How-to-use-a-Flex-Sensor-Arduino-Tutorial/ and adjustments were made as necessary

```
//Constants:

const int ledPin = 3;   //pin 3 has PWM funtion

const int flexPin = A0; //pin A0 to read analog input


//Variables:

int value; //save analog value

void setup(){

  pinMode(ledPin, OUTPUT);  //Set pin 3 as 'output'

  Serial.begin(57600);       //Begin serial communication

}

void loop(){

  value = analogRead(flexPin);         //Read and save analog value from potentiometer

  Serial.println(value);               //Print value

  value = map(value, 700, 900, 0, 255);//Map value 0-1023 to 0-255 (PWM)

  analogWrite(ledPin, value);          //Send PWM value to led

  delay(100);                          //Small delay

}
```

Conclusions/action items:

Now that the flex sensor has also been tested and is running appropriately, this code will also need to be modified to work with the linear actuator in the final code. That will be worked on tomorrow in addition to adjusting the linear actuator code.

12/2/2021 - First Draft of Code All Together

DANIELLE LEFKO - Dec 03, 2021, 2:18 PM CST

Title: First Draft of Code All Together

Date: 12/2/2021

Content by: Danielle

Present: Danielle and Stephanie

Goals: To put together the different pieces of the code into a fully functioning cascaded code

Content:

```
//Constants:
const int ledPin = 3;   //pin 3 has PWM funtion
const int flexPin = A0; //pin A0 to read analog input

//Variables:
int value; // convert analog value to scale of 0-5
int flexValue; //save analog value
int oldValue; // marker to stop movement of motor when necessary

byte Speed = 255; // Intialize Varaible for the speed of the motor (0-255);
int RPWM = 10;  //connect Arduino pin 10 to IBT-2 pin RPWM
int LPWM = 11;  //connect Arduino pin 11 to IBT-2 pin LPWM


void setup(){

  pinMode(ledPin, OUTPUT);  //Set pin 3 as 'output'
  Serial.begin(74880);   //Begin serial communication
  pinMode(10, OUTPUT); // Configure pin 10 as an Output
  pinMode(11, OUTPUT); // Configure pin 11 as an Output

// start at full retraction of motor for baseline
  //Speed = 255;
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);

  delay (7500); // max length = 7.5 seconds

  oldValue = 0; // initialize value for comparison
}

void loop(){

  flexValue = analogRead(flexPin);         //Read and save analog value from potentiometer
  value = map(value, 700, 900, 0, 255); //Map value 0-1023 to 0-255 (PWM)
  analogWrite(ledPin, value);          //Send PWM value to led // this can be removed later
  delay(100);                          //Small delay // unneccessary?

  value = flexValue * (5.0 / 1023.0);  // convert to a scale of 0-5
  Serial.println(value);               //Print value

  if(value != oldValue) {    // if value does equal old value, this means no change has been made by user
                         // and desire is to maintain that amount of flexion
  if(value <= 2) {          // full flexion of wrist = full bend in thumb desired
  // Extend Actuator at Full Speed
  //Speed = 255;
  analogWrite(RPWM, 0);
  analogWrite(LPWM, Speed);
```

```
  delay(7500); // 7.5 Seconds
  }

  else if(value <= 4) {     // partial flexion of the wrist = partial bend in thumb
// Retract Actuator to halfway
  //Speed = 255;
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);

  delay(3750); // 3.75 Seconds
  }

  else {
// Retract Actuator fully
  //Speed = 255;
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);

  delay(7500); // 7.5 Seconds

  }

  // Stop Actuator
  analogWrite(RPWM, 0);
  analogWrite(LPWM, 0);

  delay(10000); // 10 Seconds
}
oldValue = value;
}
```

Conclusions/action items:

This code includes pieces from the code to run the motor, code to input from the flex sensor, and the filtered if statements that connect them. The code takes input from the flex sensor and calculates it into a scale of 0 - 5. It determines which category the value belongs in between three different options. The first option is full flexion of the wrist, which would be full extension of the motor resulting in full extension of the thumb. The next option is half way flexion of the wrist, which would be half extension of the motor and a resulting half extension of the thumb. Finally, everything else would indicate no flexion of the wrist and no extension of the motor or thumb. The code continues to run through this loop and takes input every time. In order to prevent the motor from changing levels of extension when undesired, I added a piece that determines if the new value is different from the previous value. If it is not, the if statements are skipped all together and the code continues to input from the flex sensor. As soon as the new value is different from the old value, the code runs through the if statements again and adjusts accordingly. The next steps for this code will be to attach the circuitry and test with the prototype thumb. Once the circuitry is attached, values can be adjusted such as level of flexion and extension based on the client's needs.

12/3/2021 - First Draft of Circuit

DANIELLE LEFKO - Dec 13, 2021, 8:42 PM CST

Title: First Draft of Circuit

Date: 12/3/2021

Content by: Danielle

Present: Danielle and Stephanie

Goals: to create and document the circuitry for the prototype

Content:

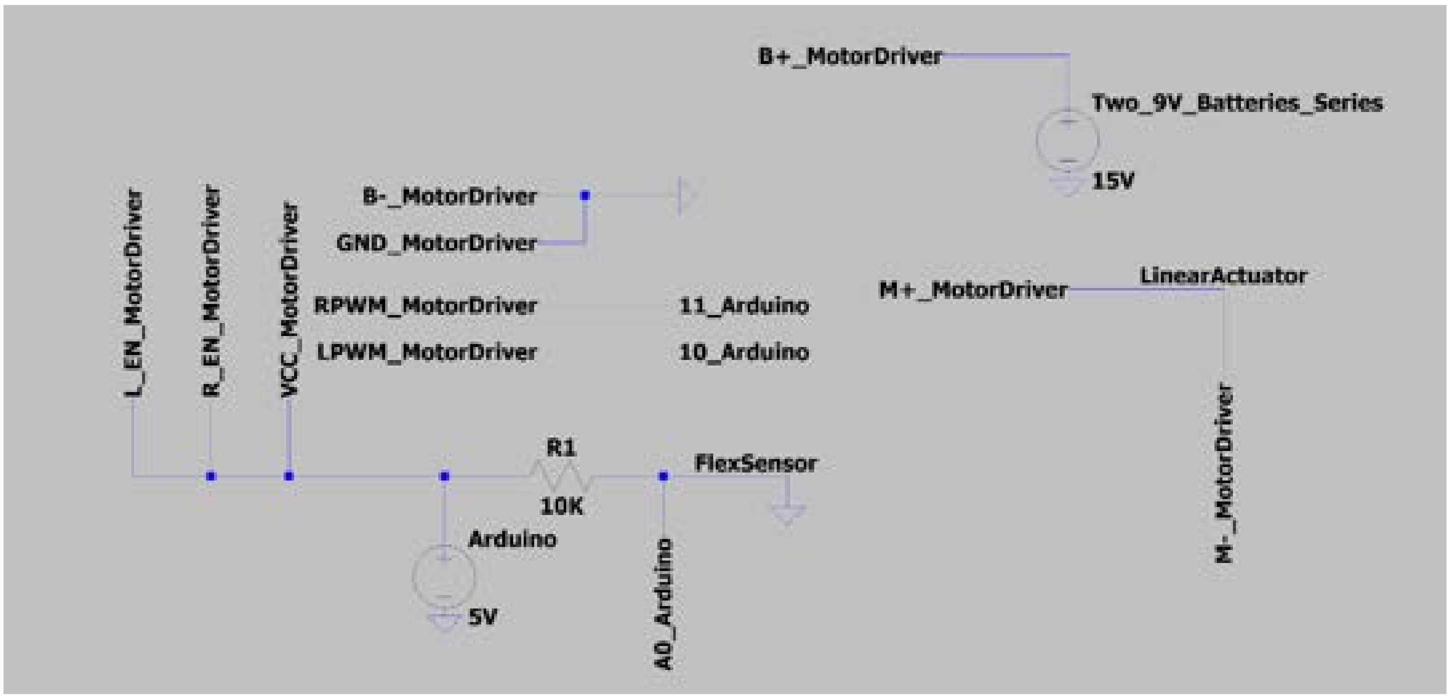


Figure above: LTSpice of the circuitry

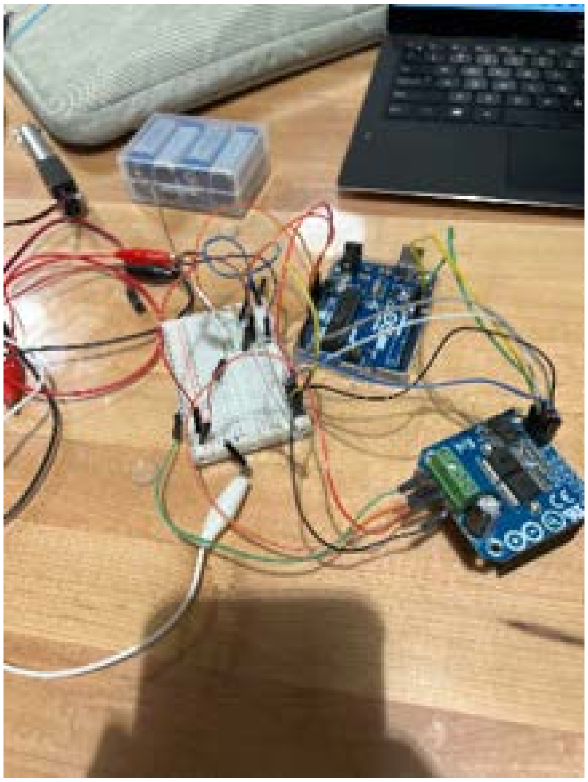


Figure above: picture of the circuitry

Conclusions/action items:

The first draft of the circuitry is designed with 4 major components: linear actuator, flex sensor, motor driver, and Arduino. The next steps will be to make this circuitry portable and fixed using soldering materials and the arduino nano.

12/7/2021 - Second Draft of Code

DANIELLE LEFKO - Dec 07, 2021, 4:11 PM CST

Title: Second Draft of Code

Date: 12/7/2021

Content by: Danielle

Present: Danielle, Stephanie, Emmalina

Goals: to make improvements to the code once it is attached to the thumb piece

Content:

```
//Constants:
const int ledPin = 3;   //pin 3 has PWM funtion
const int flexPin = A0; //pin A0 to read analog input

//Variables:
int value; // convert analog value to scale of 0-5
int flexValue; //save analog value
int oldValue; // marker to stop movement of motor when necessary

byte Speed = 255; // Intialize Varaible for the speed of the motor (0-255);
int RPWM = 10;  //connect Arduino pin 10 to IBT-2 pin RPWM
int LPWM = 11;  //connect Arduino pin 11 to IBT-2 pin LPWM
bool caught = false; // ensures that after the loop goes around once it doesn't continue to extend after it has already extended


void setup(){

  pinMode(ledPin, OUTPUT);  //Set pin 3 as 'output'
  Serial.begin(74880);   //Begin serial communication
  pinMode(10, OUTPUT); // Configure pin 10 as an Output
  pinMode(11, OUTPUT); // Configure pin 11 as an Output

// start at full retraction of motor for baseline
  //Speed = 255;
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);

  delay (7500); // max length = 7.5 seconds

  oldValue = 0; // initialize value for comparison

}

void loop(){

  flexValue = analogRead(flexPin);         //Read and save analog value from potentiometer
  value = flexValue * (5.0 / 1023.0);  // convert to a scale of 0-5
  Serial.println(value);               //Print value

  if(value != oldValue) {    // if value does equal old value, this means no change has been made by user
                             // and desire is to maintain that amount of flexion
  if(value <= 2 && !caught) { // full flexion of wrist = full bend in thumb desired
  // Extend Actuator at Full Speed
  analogWrite(RPWM, 0);
  analogWrite(LPWM, Speed);

  delay(2000); // 2 Seconds
  caught = true; // establishes that it has already gone through and extended once
  }
```

```
  //else if(value <= 4) {     // partial flexion of the wrist = partial bend in thumb
// Retract Actuator to halfway // possible addition for second semester
  //analogWrite(RPWM, Speed);
  //analogWrite(LPWM, 0);

  //delay(3750); // 3.75 Seconds
 // }

  else {
// Retract Actuator fully
  analogWrite(RPWM, Speed);
  analogWrite(LPWM, 0);
  caught = false;

  delay(2000); // 2 Seconds

  }

  // Stop Actuator
  analogWrite(RPWM, 0);
  analogWrite(LPWM, 0);

}
oldValue = value;
}
```

Conclusions/action items:

After attaching to the thumb piece, it was found that the linear actuator extended further than neccessary. The time was reduced as a result. In addition, the second step of extension at a shorter length was found to be too precise with the small space between the thumb and the fingers. This can be revisited at a later point when we meet with the client in person. The next steps will be to add the appropriate durations once the prosthetic is fitted to the client.

9/16/21 Anatomy of Hand

KAREN SCHARLAU (kscharlau@wisc.edu) - Oct 20, 2021, 11:03 AM CDT

Title: Anatomy of Hand

Date: 9/16/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To understand the anatomy of a hand and know the names of the joints and bones.

Content:

- It is important to be able to describe exactly what the problem is in the PDS document. In order to do so, I read about hand anatomy

- The joint that the client can move in his pinky is called the metacarpophalangeal joint. There are many different bones that make up the hand. Perhaps the prosthetic would do best to mimic nature and the structure of bones that are naturally in the hand, then use strings as tendons.

-The human forearm is made up of two bones called the Radius and Ulna

- The carpal tunnel is a passageway for many nerves in the hand. It may be possible for the team to find this place on the patient and use the signals from it to control the flexion of the prosthetic.

- During tight gripping, the fifth finger (the pinky finger) is pulled down and over. This may indicate the position in which the pinky can produce the most force. The patient still has his pinky, so maybe it would work to place the thumb in a position where he can produce the most force with his natural pinky.

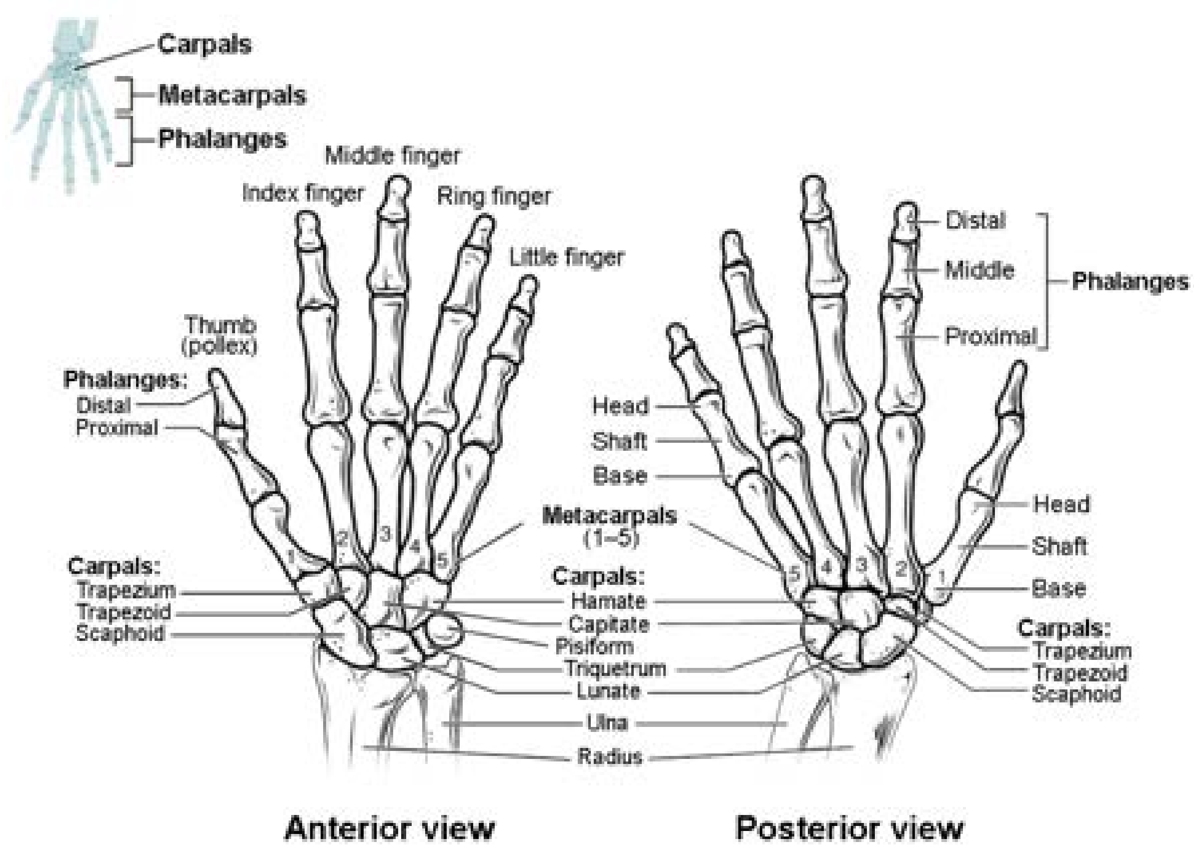


Figure 1: The anterior view of a skeletal hand. Figure 2: Posterior view of a skeletal hand.

https://courses.lumenlearning.com/ap1/chapter/bones-of-the-upper-limb/

L. L. & OpenStax, “Anatomy and physiology I,” *Lumen*. [Online]. Available: https://courses.lumenlearning.com/ap1/chapter/bones-of-the-upper-limb/. [Accessed: 16-Sept-2021].

Conclusions/action items:

I can now describe the movements the client has in their hand so that someone reading the PDS will understand what the problem is. This will help the team and I communicate better with the occupational therapist client and with anyone who reads our reports in the future.

9/24/21 Force Distribution

KAREN SCHARLAU (kscharlau@wisc.edu) - Oct 20, 2021, 10:59 AM CDT

Title: Force Distribution

Date: 9/24/21

Content by: Ren Scharlau

Present: Ren Scharlau

Goals: To understand what forces we might need in our prosthetic hand.

Content:

- The grip of a hand will directly determine its functionality.
- The natural hand has many points of contact with an object that it holds
  - It would be useful to mimic this in order to have the best grip possible
- This study analyzes force distributions of prosthetic hands compared to the functional natural human hand
- A cylinder is held and contact forces all over the hand are measured and analyzed
- This is very useful to consider when holding a cup or similarly shaped object, but for picking up irregular objects, it may not be as applicable in our particular project
- The study found that the largest forces are applied in the thumb, pointer, and middle finger
  - The patient has only his ring and pinky finger, so if we add a thumb, pointer, and middle finger, they may need to have the most grip force. This may feel unnatural to the patient, however, because it has been a couple years since his injury and is likely used to living with his pinky finger as the most dominant finger.

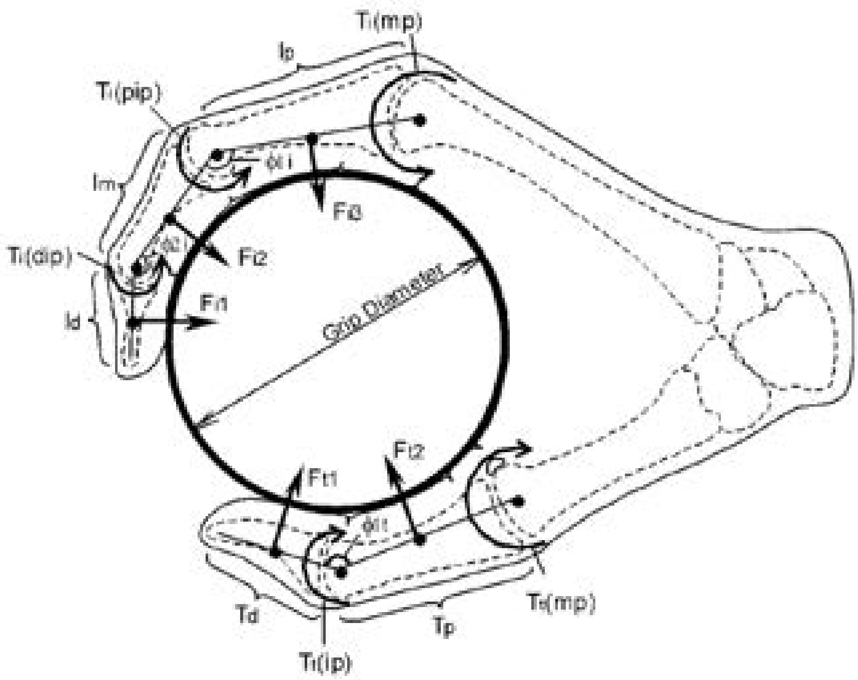


Figure 3 Orientation of contact forces (F_{index}) measured by sensors. Torques (T_{index}(joint)) produced at finger joints: ip – interphalangeal joint; mp – metacarpophalangeal joint; pip – proximal interphalangeal joint; dip – distal interphalangeal joint. Index of phalangeal lengths (T_{index}) and (I_{index}) between finger joints: p – proximal, m – middle, d – distal. Joint angles φindex .

Kargov, Artem & Pylatiuk, Christian & Martin, Jan & Schulz, Stefan & Döderlein, Leonhard. (2004). A comparison of the grip force distribution in natural hands and in prosthetic hands. Disability and rehabilitation. 26. 705-11. 10.1080/09638280410001704278.

Conclusions/action items:

I will consider these grip forces in designs that are created. This has made me aware that we need to design the hand so that in contacts surfaces at multiple points to increase grip strength.

9/18/21 Current Prosthetic costs and designs

KAREN SCHARLAU (kscharlau@wisc.edu) - Oct 20, 2021, 11:06 AM CDT

Title: Current Prosthetic costs

Date: 9/18/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To understand the price point of a top-of the line prosthetic to show how we are helping the client by creating a budget hand.

Content:

There are tons of different types of hand prosthetics. The fully functional hands tend to be very expensive. This website gives ranges of prices, and they can be an upwards of 60,000 dollars. The client is currently not working, and he doesn't have any money to put towards the project. The funding is currently our largest challenge. It would be a good idea for us to get funding from an outside source or through the University.

The website also shows a diagram for how the bionic finger works. This may be helpful to reference when creating our own design. It looks like using a linear motor could be a very compact option compared to servo motors I was expecting to need to use. It looks like when the linear motor fires, it causes the tip of the finger to bend. This would aid in good gripping forces.

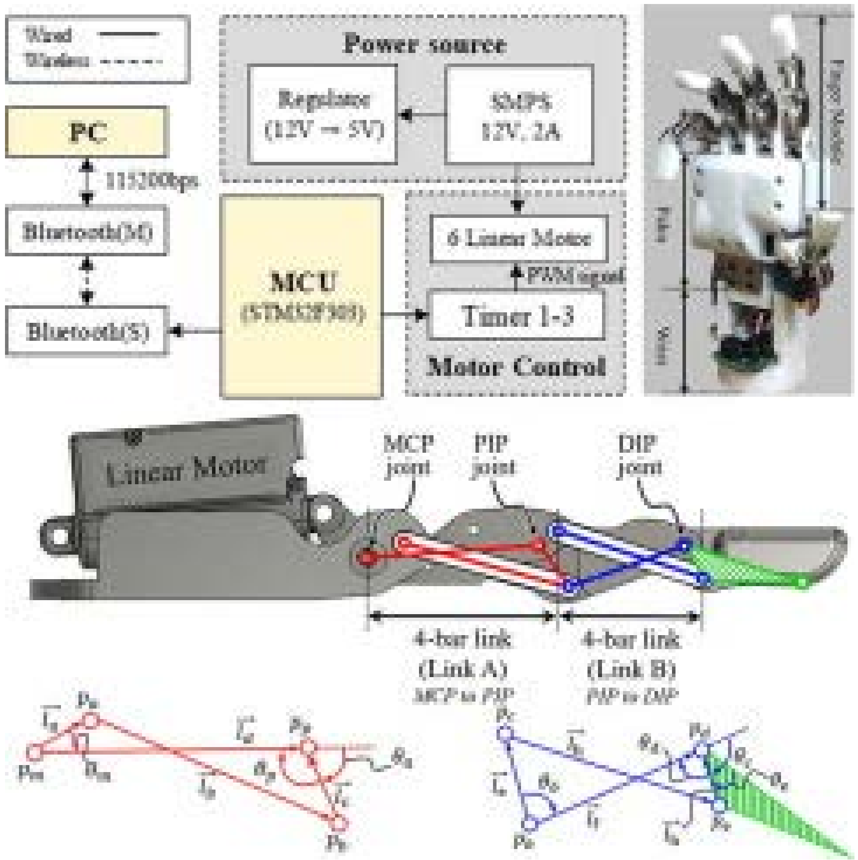


Figure 4: A linear motor design for how a prosthetic finger can bend.

Another design:

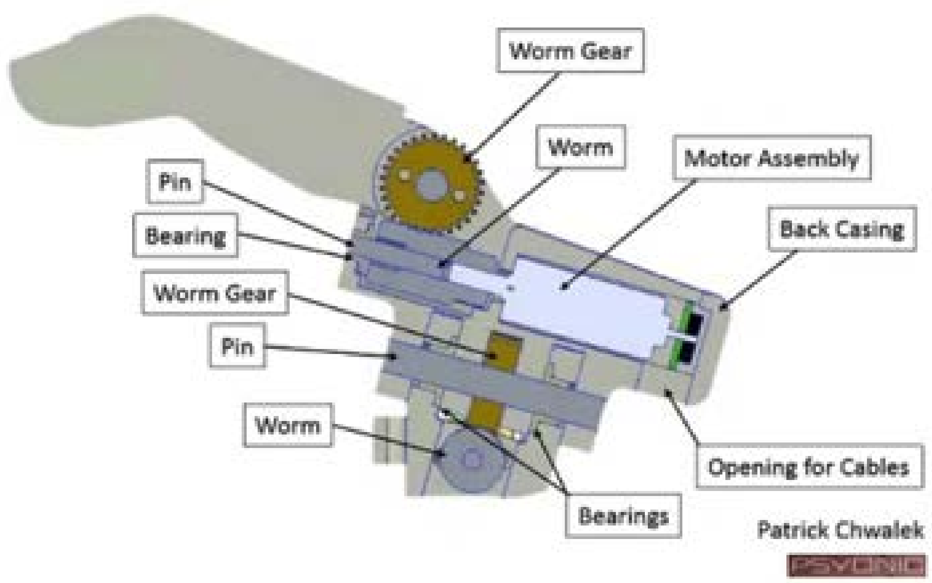


Figure 5: A prosthetic design that uses a gear and a linear motor to move the finger.

This design uses a linear motor plus a gear. It seems like the use of the gear would increase the force of bending that we have, which could increase grip. It also uses a linear motor, similar to the other design. This finger would not move as naturally as the other design, but perhaps the team could modify it so that it does.

https://bionicsforeveryone.com/bionic-arms-hands/

W. Williams, “A complete guide to bionic arms & hands,” *Bionics For Everyone*, 01-Oct-2020. [Online]. Available: https://bionicsforeveryone.com/bionic-arms-hands/. [Accessed: 20-Oct-2021].

Conclusions/action items:

Funding for our project is very important, and in order to build a functional hand, we will need money to buy it. The prices of prosthetic hands on the market today are very high, so it will help our client a lot to build one on a budget. I will share these design ideas with the team.

9/28/21 Competing Designs

KAREN SCHARLAU (kscharlau@wisc.edu) - Oct 20, 2021, 11:12 AM CDT

Title: Competing Designs

Date: 9/28/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To learn more about what is currently on the market for the patient.

Content:

The Taska Hand

- 
- Figure 6: The Taska Hand.
  - Pros: Natural movements, waterproof, durable, replaceable finger pads, knuckle locking
  - Cons: Expensive, Five fingers(we only need the thumb),
  - https://www.taskaprosthetics.com/products/taska-hand
  - “The forecast is bright, even in wet weather.,” *do more - TASKA tag line*. [Online]. Available: https://www.taskaprosthetics.com/products/taska-hand. [Accessed: 20-Oct-2021].

The bebionic

- Figure 7: The Bebionic hand design.
    - Pros: 14 different grip patterns, individual motors in each finger, based on muscle signals, looks natural
    - Cons: Expensive, Motors that small and robust/strong would cost far too much
    - https://www.ottobockus.com/prosthetics/upper-limb-prosthetics/solution-overview/bebionic-hand/
    - “Bebionic hand,” *ottobock.* [Online]. Available: https://www.ottobockus.com/prosthetics/upper-limb-prosthetics/solution-overview/bebionic-hand/. [Accessed: 20-Oct-2021].
- **The i-limb**
    - 
    - Figure 8: the i-limb hand design.
    - Pros: myoelectric, individually powered digits, anti-drop safety feature
    - Cons: expensive!!!, not waterproof
    - https://www.ossur.com/en-us/prosthetics/arms/i-limb-ultra
    - “Össur. life without limitations.,” *Össur. Life Without Limitations.* [Online]. Available: https://www.ossur.com/en-us/prosthetics/arms/i-limb-ultra. [Accessed: 20-Oct-2021].

Conclusions/action items:

These prosthetic hands are unreasonably expensive, but the team can focus on creating a budget version of them. We may be able to incorporate some of the features into our prosthetic to make it very usable and natural. By making it more affordable, people without insurance, or low income patients like our client will be able to regain usability in their hand. I will share the best features of the hands with the team.

9/27/21 Preliminary Design Ideas

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 12:01 PM CST

Title: Preliminary Design Ideas

Date: 9/27/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: Get some ideas about how we can make a prosthetic that meets the specifications.

Content:

Based on the fact that the patient can move their wrist slightly tells me that they have some muscular activity in their wrist. I think that we should try to capitalize on this by using EMG's. These are electrodes that can sense muscle electrical activity. I am hoping to find a reasonable-cost one. There are even some that have variable power that react to different amounts of stimuli. This could be very useful in controlling the gripping function of the hand. The more the muscles fire, the more the prosthetic could flex. This method is also helpful for the patient since we will be able to amplify the signal, meaning his wrist does not need to flex as much as the mechanical designs. It may be a good idea as well to have some sort of sensory input back to the patient for a sense of feeling. This may not be necessary, however, if we primarily use his natural pinky finger for gripping.

https://www.statnews.com/2020/04/30/mind-controlled-prosthetic-arm-patients-feel-objects/#:~:text=The%20prosthetic%20hand%20is%20controlled,sensory%20feedback%20while%20grasping%20objects.

S. Z. A. 30, S. Zia, L. Says: and M. G. says: “Prosthetic arm enables patients to feel the objects they grip,” *STAT*, 30-Apr-2020. [Online]. Available: https://www.statnews.com/2020/04/30/mind-controlled-prosthetic-arm-patients-feel-objects/#:~:text=The%20prosthetic%20hand%20is%20controlled,sensory%20feedback%20while%20grasping%20objects. [Accessed: 20-Oct-2021].

Conclusions/action items:

I will discuss using EMG's with the team. EMG's would be a good universal way to control prosthetics because you can measure muscle activity anywhere in the body. I will find a way to test this theory in the future to see if EMG's are a viable option for the project on both the small and large scale manufacturing.

10/6/21 Hand attachments and designs

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 12:02 PM CST

Title: Hand Attachments and Designs

Date: 10/6/21

Content by: Ren Scharlau

Present: Ren Scharlau

Goals: To get some ideas about the prosthetic hand documented.

Content:

https://www.armdynamics.com/our-care/finger-and-partial-hand-prosthetic-options

- In this design, the myoelectric sensors are on the wrist attachement.
-

https://www.armdynamics.com/upper-limb-library/introduction-to-myoelectric-prostheses

- I am worried that our design might be too bulky if we are using a separate motor for each finger.
- This design is very compact and would be good to mimic
    - The linear motor would save us space
- This design saves space and looks like it would bend naturally
- I also think we should make a skin covered silicone glove to fit over it to offer the best cosmetics - which is the main priority of the patient.

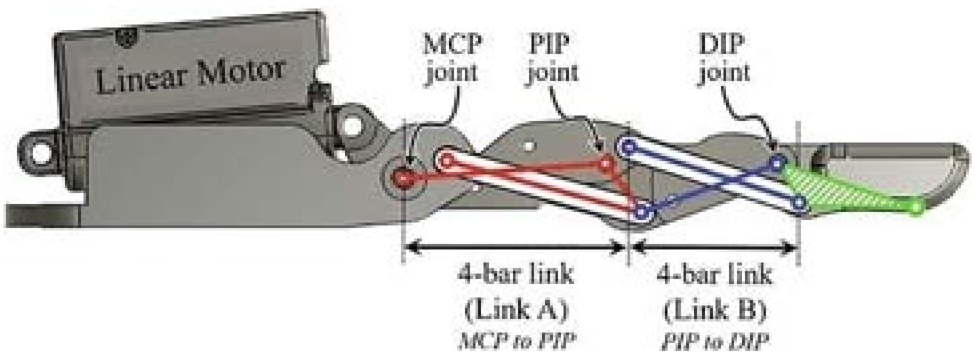


Figure 1: A model of a prosthetic finger that would bend naturally and provide grip force.

https://bionicsforeveryone.com/bionic-arms-hands/

W. Williams, “A complete guide to bionic arms & hands,” *Bionics For Everyone*, 01-Oct-2020. [Online]. Available: https://bionicsforeveryone.com/bionic-arms-hands/. [Accessed: 20-Oct-2021].

Conclusions/action items:

Share ideas with the team at the next meeting. Make a CAD model of the thumb similar to this. Propose using a linear motor for the design to save space.

10/8/21 EMG

KAREN SCHARLAU (kscharlau@wisc.edu) - Oct 19, 2021, 7:55 PM CDT

Title: EMG

Date: 10/8/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To better understand EMG sensors that we could use to control the prosthetic thumb flexion.

Content:

In order to figure out if the EMG sensor will work on grafted skin, it would be easiest to send some EMG sensors to our client to test if they will work. This should be done as soon as possible to ensure our design can move forward. I will learn more about how the sensors work, which sensors we should use, how much they cost, and how the client can easily test if they will work.

An EMG sensor measures the electrical signals that the muscles generate. The brain decides which muscles to move, and the motor cortex outputs an electrical action potential down the spinal cord. When this action potential reaches the muscles, a release of Calcium causes the actin and myosin to bind, and when the depolarization is high enough, they pull together, causing contraction of a muscle.

Our team will most likely want to use Surface EMG sensors because a non-invasive sensor will have a much lower risk associated. To use a surface EMG sensor, two electrodes are placed on the skin to detect electrical signals. Normal results will show no electrical activity when the muscle is at rest, and as the muscle is contracted, there will be higher amplitudes of signals. The GROVE - EMG Detector is a device used to detect EMG signals. It comes with electrodes, but they look like they are sticky pads, which will wear out. Ideally for our project, we want electrodes that can be used over and over again.

The placement of the electrodes will be important in detecting signals as accurately as possible. We are looking at wrist flexion specifically. According to "Recommended Surface EMG Electrode Position for Wrist Extension and Flexion", we will have the best results from placing the electrodes at 90% of the forearm length (towards the elbow).

Surface electrodes come in both wired and wireless options. The EMG sensors from biometrics LTD also require little skin surface preparation, which would make using the device less of a hassle for the patient.

For our design: Three EMG sensors will be used to sense the muscle activity in the patient’s arm. One will be negative, one will be positive, and one will be grounded. The positive and negative electrodes will be placed in the middle and at the end of the flexor carpi ulnaris. The ground electrode will be placed near a bone to ground the signal. The signal will then be passed through a differential amplifier. This is what will allow the signal to be amplified. Then the signal will pass through a high pass filter and a low pass filter. These are simple filters that use resistors in order to only use signals within a specified range. This will lessen the noise of the signal. The team expects to receive signals from the muscles between 50 and 150 hertz. Anything out of this range will be filtered out.

https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7435877

https://www.electronicsforu.com/electronics-projects/wireless-emg-control-prosthetics

https://www.biometricsltd.com/surface-emg-sensor.htm

Conclusions/action items:

I will share this new information with the team. I will also get a quote for these surface EMG sensors to find out if they may be in our budget. Surface EMG sensors can be used pretty much universally across patients, so if another device was created, it is likely that these same sensors could be used. It is also useful to know more about the EMG sensors and how we might set them up.

10/12/21 Design Change

KAREN SCHARLAU (kscharlau@wisc.edu) - Oct 19, 2021, 8:00 PM CDT

Title: Design Change

Date: 10/12/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To come up with design ideas that help the patient get what he wants in light of the new information the team learned.

Content:

Initially, the team was told that the patient preferred a cosmetic approach over functionality of the hand. Our designs reflected this. After meeting with the client, the team found out that the patient wants to be able to go back to work, and to do so, he needs a functioning hand. This changed the team's priorities, and we have changed our designs accordingly. The team also found out that there is pain in the hand at the point where the fingers used to be attached. This also changes the design, because we need to reposition things.

The attachment to the hand must change. I think it will be most stable if we can velcro two formed pieces of hard plastic around his hand and forearm as a sort of brace. To increase his usability, I think there should be a specific writing attachment. I think it also may be a useful to have a hook that flips out to carry things like bags easily.

Conclusions/action items:

I will brainstorm design ideas that will allow our team to create a device that the client will be happy with. I will create a solidworks model of the attachment and share with the team. I will try to make the design customizable and versatile so that it can be used in other applications as well.

10/15/21 EMG code

KAREN SCHARLAU (kscharlau@wisc.edu) - Oct 20, 2021, 11:18 AM CDT

Title: EMG code

Date: 10/15/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: Understand more about what our code will need to do and what it might look like.

Content:

The EMG sensors will require code to follow in order to know when to flex the prosthetic thumb. I took a coding class a couple semesters ago and have used an arduino in a couple different classes. I know that code can be a pain to write sometimes, so I wanted to have an idea of where we can start when we get to that point in our project. The website I found shows code that one group used to read EMG sensors. The code that our particular prosthetic uses will likely be different, but this could give the team a backbone to start on, which could cut down the amount of time it takes to get the prosthetic up and working.

Sample Code from website:

```
// Grove - EMG Sensor demo code
// This demo will need a Grove - Led Bar to show the motion
// Grove - EMG Sensor connect to A0
// Grove - LED Bar connect to D8, D9
// note: it'll take about serval seconds to detect static analog value
// when you should hold your muscle static. You will see led bar from level 10 turn to
// level 0, it means static analog value get ok

#include <LED_Bar.h>

LED_Bar bar(9, 8);

int max_analog_dta = 300; // max analog data
int min_analog_dta = 100; // min analog data
int static_analog_dta = 0; // static analog data


// get analog value
int getAnalog(int pin)
{
long sum = 0;

for(int i=0; i<32; i++)
{
sum += analogRead(pin);
}

int dta = sum>>5;

max_analog_dta = dta>max_analog_dta ? dta : max_analog_dta; // if max data
min_analog_dta = min_analog_dta>dta ? dta : min_analog_dta; // if min data
```

```
return sum>>5;
}

void setup()
{
Serial.begin(115200);

long sum = 0;

for(int i=0; i<=10; i++)
{
for(int j=0; j<100; j++)
{
sum += getAnalog(A0);
delay(1);
}

bar.setLevel(10-i);
}

sum /= 1100;

static_analog_dta = sum;

Serial.print("static_analog_dta = ");
Serial.println(static_analog_dta);
}

int level = 5;
int level_buf = 5;

void loop()
{

int val = getAnalog(A0); // get Analog value

int level2;

if(val>static_analog_dta) // larger than static_analog_dta
{
level2 = 5 + map(val, static_analog_dta, max_analog_dta, 0, 5);
}
else
{
level2 = 5 - map(val, min_analog_dta, static_analog_dta, 0, 5);
}

// to smooth the change of led bar
if(level2 > level)
{
level++;
```

```
}
else if(level2 < level)
{
level--;
}

if(level != level_buf)
{
level_buf = level;
bar.setLevel(level);
}

delay(10);
}
```

https://www.seeedstudio.com/blog/2019/12/29/what-is-emg-sensor-myoware-and-how-to-use-with-arduino/

S. 2 years ago, Shawn, S. S. author's posts, and S. author's posts, “What is EMG sensor, Myoware and how to use with Arduino?,” *Latest Open Tech From Seeed*, 05-Jul-2021. [Online]. Available: https://www.seeedstudio.com/blog/2019/12/29/what-is-emg-sensor-myoware-and-how-to-use-with-arduino. [Accessed: 15-Oct-2021].

Conclusions/action items:

This website will help the team expedite the fabrication process. I will let the team know the information that I have found.

10/18/21 Prosthetic Cuff

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:38 PM CST

Title: Prosthetic Cuff

Date: 10/18/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To design a way for the prosthetic thumb to attach to the patient without pain.

Content:

I wanted to ensure that the patient's sensitive areas on his hand were not bothered by our design. For this reason, I decided we should attach to the forearm with a secure hold. The thumb design will be mounted onto the cuff, along with electronics and motors. In this design, velcro straps will connect each pair of slots. The side with 4 slots will be adjusted to the patient, then can stay at this adjustment. The side with two slots will be the side the patient uses to put on and take off the prosthetic. The client will need to put the prosthetic on with one hand, so the simple velcro straps will allow him to do so. To maximize the comfort and safety of the patient, a silicone sock will be fitted to the patient's arm, and rest in between the prosthetic and the skin.

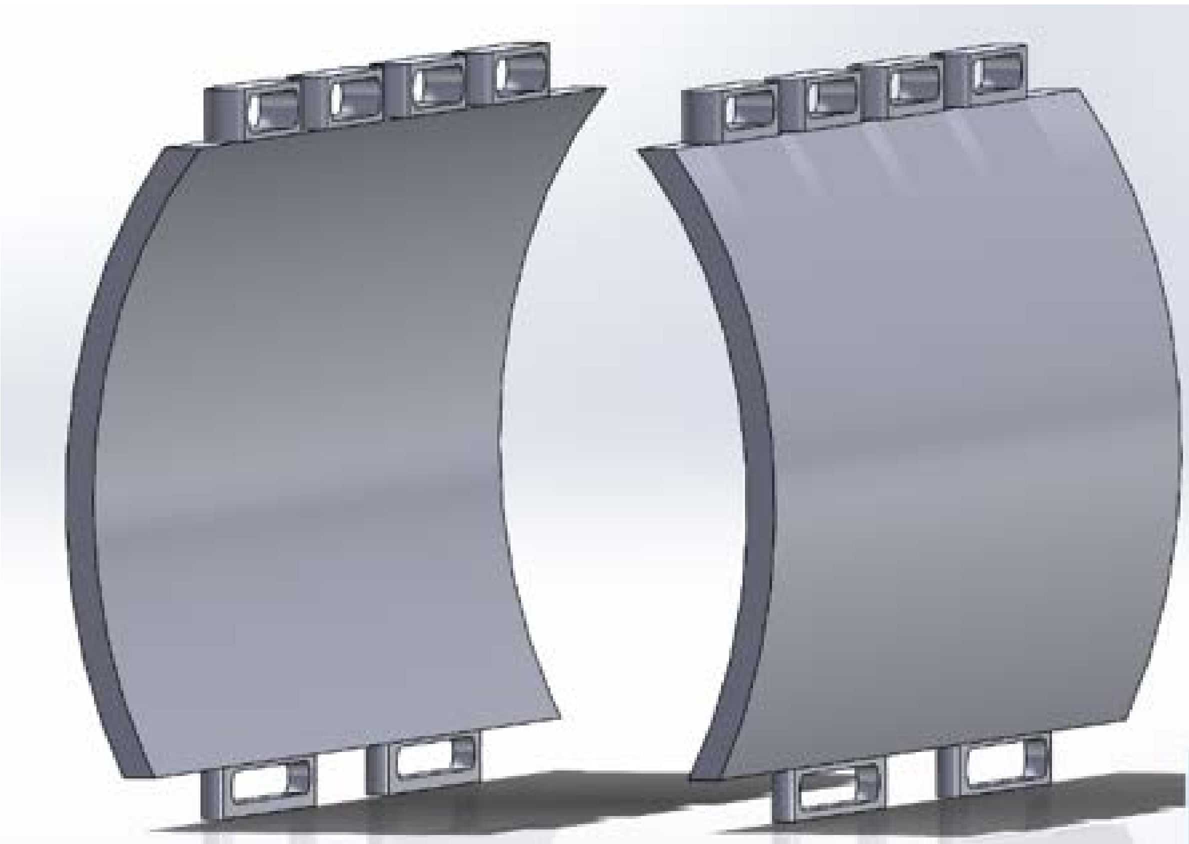


Figure 2: Cuff Design.

Conclusions/action items:

I will share my design with the rest of the team. This design is easily adjustable to fit many different arm types comfortably and can be adjusted throughout life. For this reason, it would be a good design for larger manufacturing of prosthetics.

10/23/21 Flex Sensor

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:39 PM CST

Title: Flex Sensor

Date: 10/23/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To simplify the team's design with the use of a flex sensor.

Content:

While the myoelectric sensors would be really cool to have for this prosthetic, it may be a long leap for the team to get a functioning hand by December. Additionally, it would be difficult to actually test these sensors on the patient, since he is far away and doesn't seem to be inclined to meet with us very much. To simplify the electronics of this device, I would like to implement a flex sensor. This way the team can still use wrist flexion, or perhaps pinky flexion to control the movement of the thumb. The flex sensor is a cheap strip that connects to an arduino which senses the amount of flex. It is small and easy to hook up to an arduino, so I think this would be a good option for the team.

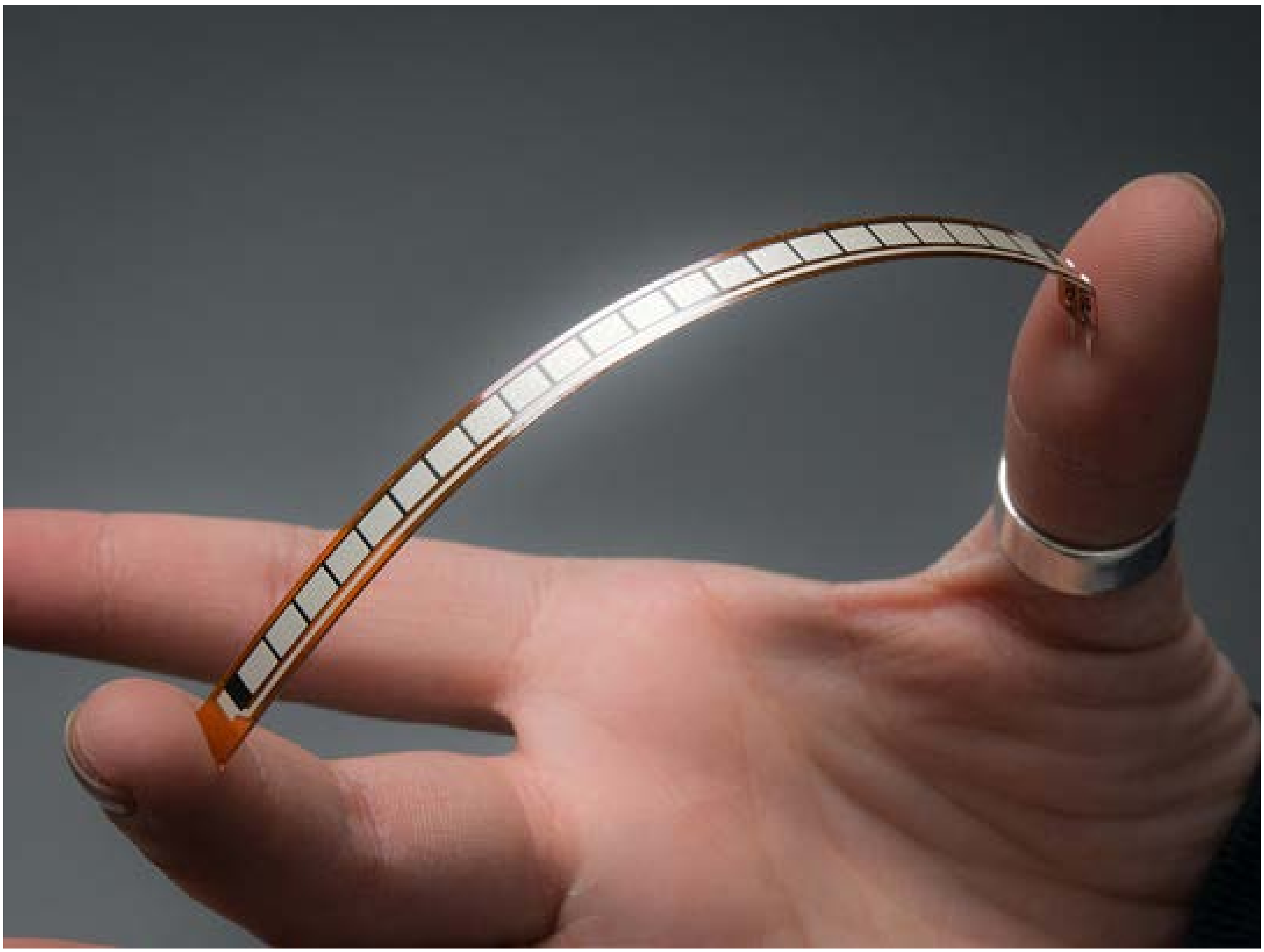


Figure 3: A picture of the flex sensor. https://www.adafruit.com/product/182?gclid=CjwKCAjwzt6LBhBeEiwAbPGOgWYhU4Uh7PLdXuXvxR_Y9ZQ3fhJozce2tykNTGc5aGk1-uCDDF1cWhoCf9UQAvD_BwE

This flex sensor is only $12.95, which would is very affordable for low-income prosthetics. Hooking the sensor up to the arduino is pretty simple as well.

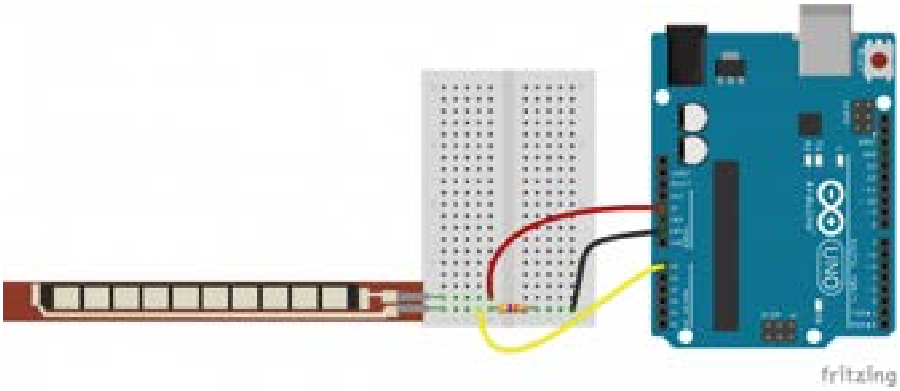


Figure 4: An example of a flex sensor being hooked up to an arduino. https://learn.sparkfun.com/tutorials/flex-sensor-hookup-guide/example-circuit.

This is very straight forward, and I feel that I would be very capable of getting this system to work.

A. Industries, “Long flex sensor,” *adafruit industries blog RSS*. [Online]. Available: https://www.adafruit.com/product/182?gclid=CjwKCAjwzt6LBhBeEiwAbPGOgWYhU4Uh7PLdXuXvxR_Y9ZQ3fhJozce2tykNTGc5aGk1-uCDDF1cWhoCf9UQAvD_BwE. [Accessed: 23-Oct-2021].

Flex Sensor Hookup Guide. [Online]. Available: https://learn.sparkfun.com/tutorials/flex-sensor-hookup-guide/example-circuit. [Accessed: 23-Oct-2021].

https://create.arduino.cc/projecthub/python_everyday/interfacing-arduino-with-flex-sensor-and-servo-motor-b25b49?ref=part&ref_id=8233&offset=9

Conclusions/action items:

Share this new design idea with the team and with Mitch at the advisor meeting on Wednesday. The flex sensor is an affordable sensor that can be used in many different ways. It could be customized to the person in need of a prosthetic, so once the team can make this design, it is possible to make similar designs for other people.

10/25/21 Gear Design

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:39 PM CST

Title: Gear Design

Date: 10/25/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To figure out how the prosthetic thumb should move.

Content:

I came up with a design that consists of various gears in order to move a thumb-like appendage. The flex sensor would sense how much the wrist or pinky is bending, and would signal to a motor how much to spin. This would be a very sturdy design. I still need to design the supports, but I wanted to see if this configuration of gears looked promising first. I think that they do. In the picture below, the yellow arrows indicate the movement of each segment. The red arrows indicate the direction of the gears. The black lines represent segments and supports.

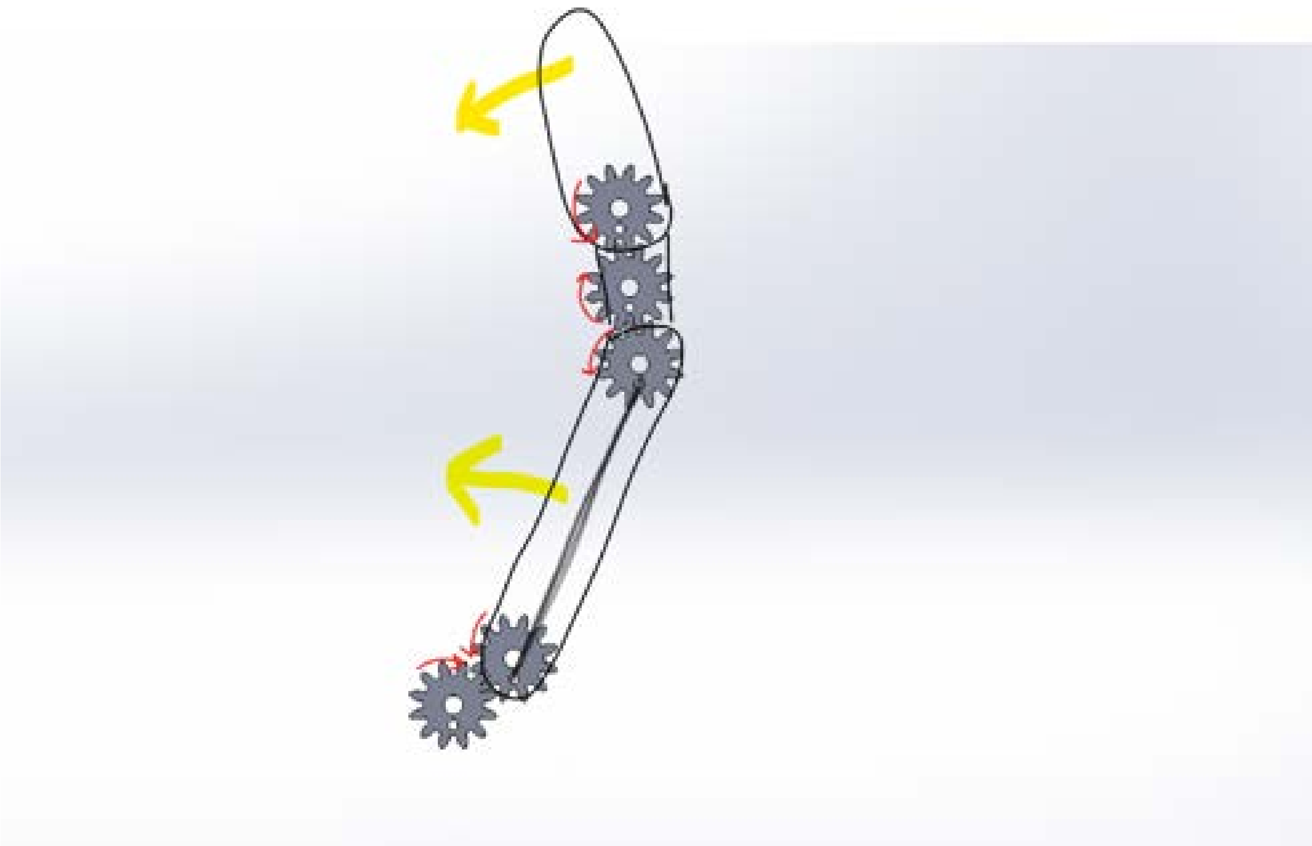


Figure 6: Design of how the thumb could move. The gears would spin in the direction of the red arrows, the segments would move in the direction of the yellow arrows as a result, and the black lines represent the segments and the support.

Conclusions/action items:

I will show this design to the team to see if they like if or want to make any modifications to it. This would likely be paired with a flex sensor and a motor. It would be a very reliable and sturdy design, not to mention, affordable to low-income people.

10/31/21 Carbon Fiber Manufacturing

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:40 PM CST

Title: Carbon Fiber Manufacturing

Date: 10/31/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: I will be looking into whether carbon fiber is a viable material for the team to use and fabricate.

Content:

Carbon fiber is a very strong material, and I am considering using it for the cuff part of the design. I will be looking into whether carbon fiber is a viable material for the team to use and fabricate.

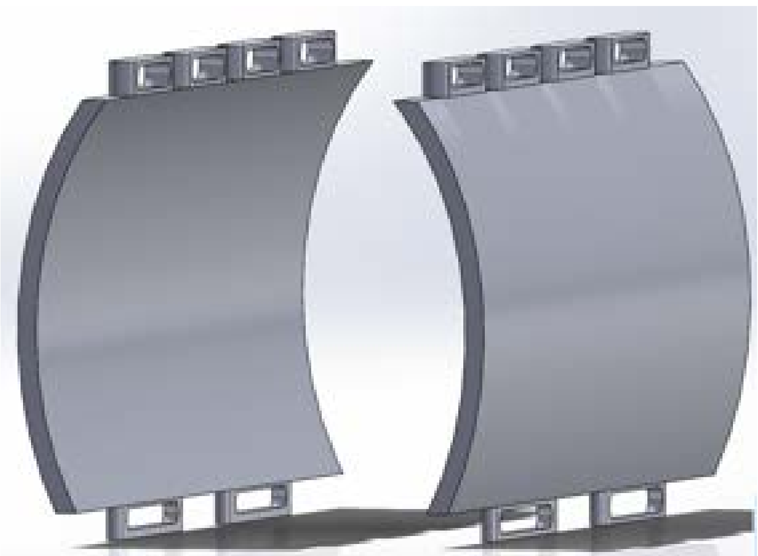


Figure 7: A picture of the proposed cuff design. The carbon fiber would need to be formed into a shape similar to this, and be strong and sturdy in this shape.

Carbon fiber is a light, yet strong reinforced composite plastic. It is stronger that aluminum, but much lighter. The fibers are held together with a hard resin. The alignment of the fibers and the type of resin used can give it different properties. Epoxy, polyester, and vinyl ester are three common resins that are used. Epoxy offers the most strength, the lightest weight, and longest shelf life, but it is the most expensive and difficult to manufacture. This does not seem like a great option for the team due to the manufacturing difficulty. Polyester has ease of use, can withstand exposure to sun, and is cheap, but is susceptible to breaking and corrosion. The low cost is a big benefit to the team because there is a limited budget for the project. Vinyl ester has properties that make it a mix between the two previously discussed, which makes it seem the most viable for the team at the moment.

Among the methods to create carbon fiber, the wet-layup method seems the easiest and lowest cost for the team. We would need the fibers, the resin, and a mold in the shape that we want. Molds can be 3D printed, which is easy enough to do at the Makerspace.

https://formlabs.com/blog/composite-materials-carbon-fiber-layup/

“How to manufacture carbon fiber parts,” *Formlabs*. [Online]. Available: https://formlabs.com/blog/composite-materials-carbon-fiber-layup/. [Accessed: 31-Oct-2021].

Conclusions/action items:

I will share what I learned about carbon fiber with the team in our next meeting. It is a viable option, but the supplies may be difficult to get because the team can only get items off of ShopUW. We also want to make the process scalable so that there is a possibility of producing many similar prosthetics on a larger scale.

11/01/21 Materials & Budget

KAREN SCHARLAU (kscharlau@wisc.edu) - Nov 27, 2021, 6:20 PM CST

Title: Materials and Budget

Date: 11/27/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To organize what the team needs and where we can get materials.

Content:

I went through and found all the specific materials that we should order. I then organized them into a table for the convenience of the team. There will need to be a budget proposal submitted by the team in order to secure funding for the project. The best way to get approved for the funding is to make a summary of why we need the money and specifically where/what it will be spent on. The details will make the proposal more robust for the team. I want to get the budget proposal done as fast as possible because sometimes administrative decisions take a long time to make, and I want to make sure the team has enough time to order the materials and work on the project.

Table 1: A summary of the materials needed for the projects, what they are needed for, the suppliers, and the cost. The yellow highlights indicate sections that need more work.

Item	Description	Manufacturer	Quantity	Price	Total
3D Printing PLA	Plastic for 3D printing	UW Makerspace	N/A	$ 50.00	$ 50.00
3D Print	Plastic for Printing thumb model	UW Makerspace	N/A	?	
3D printed waterproof circuitry	Waterproof box for circuitry	UW Makerspace	N/A	?	
Carbon Fiber	Cuff base material	Can't find: Maybe need to 3d print?			
Velcro Straps	Cuff Attachment 1/2"x4"	Envisioned	1	$ 14.87	$ 14.87
Wiring	Electrical connections	Plusivo	1	$11.99	$ 11.99
Closed-Cell Foam	Cushioning for cuff	Storystore	1	$ 14.99	$ 14.99
Arduino Nano Every	Microcontroller	Arduino	1	$ 12.90	$ 12.90
Linear Motor	Prosthetic movement	USLICCX	1	$ 35.00	$ 35.00
Flex Sensor	Sensor for movement	Adafruit	1	$ 12.95	$ 12.95

Soldering Wire	Sauder wired connections	Yi Lin	1	$ 8.99	$ 8.99
Shrink Wrap	Waterproofing wire connections	Wirefy	1	$ 13.99	$ 13.99
9 V Rechargeable Batteries	Motor Power	EBL	1	$ 26.99	$ 26.99
Glue	Wire placement and waterproofing	Gorilla Glue	1	$ 12.33	$ 12.33
Arm Sleeve	Cushion between cuff and forearm	IovyoCoCo	1	$ 13.24	$ 13.24
Liquid Latex?		Are we still doing this? What is this for?			
Silicone Mold		Still doing this?			
Motor Driver	Switches polarity of motor	HiLetgo	1	10.99	10.99
Shipping costs				X	X
				Cost Total:	239.23

Conclusions/action items:

I will share this table with my team on our shared google drive. I will get their take on the yellow highlights and make the necessary changes. After writing out a paragraph describing our need for the money, I will format the proposal to match the example that Mitch sent to the team. Then I will send it to Mitch for proofreading. If the budget proposal can be finished in the next couple of days, the team will be on a good schedule for being able to order materials and work on the project.

11/02/21 Budget Proposal

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:42 PM CST

Title: Budget Proposal

Date: 11/11/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To document the finished budget proposal.

Content:

The budget proposal was finished, and sent to the administration. The team is hoping to get around $500 to create the prosthetic.

Prosthetic Hand Budget Proposal

BME 400

Emmalina Groves, Stephanie Silin, Danielle Lefko, Ren Scharlau

Advisor: Mitchell Tyler

Problem Statement: An active prosthetic right thumb is being created to assist an individual in performing daily tasks such as grasping an object. This is an important next step for the patient to gain mobility, independence, and a job. The Pro Hand design is a mobile mechanical and electronic prosthetic thumb to aid the patient in these goals of achieving functional motion and greater autonomy.

Background: The patient had a severe and aggressive infection on their right (dominant) hand, resulting in the amputation of the thumb, index, and middle fingers. It also caused loss of function in the ring finger and reduced mobility of both the pinky finger and wrist. Autografts on the forearm and remaining hand add to the challenge of creating a comfortable and functional prosthetic.

Request: The patient is unable to obtain employment due to their disability, and does not have insurance that will cover the cost of a prosthetic device. Consequently, the client, an occupational therapist, has indicated there are no funds available for this project from either the patient or the client.

The Pro Hand team is requesting $409.78 to fund the cost of materials and fees necessary to complete this project. The anticipated materials, costs, and and ancillary expenses are outlined below:

Table 1: Summary of budget.

Item	Description	Manufacturer	Quantity	Price	Total
3D Printing PLA	Plastic for 3D printing	UW Makerspace	N/A	$ 50.00	$ 50.00
3D Print	Plastic for Printing thumb model	UW Makerspace	N/A	$ 15.00	$ 15.00

3D printed waterproof circuitry	Waterproof box for circuitry	UW Makerspace	N/A	$ 50.00	$ 50.00
Carbon Fiber	Cuff base material	Grainger	1	$ 18.82	$ 18.82
Velcro Straps	Cuff Attachment 1/2"x4"	Envisioned	1	$ 14.87	$ 14.87
Wiring	Electrical connections	Plusivo	1	$ 11.99	$ 11.99
Closed-Cell Foam	Cushioning for cuff	Storystore	1	$ 14.99	$ 14.99
Arduino Nano Every	Microcontroller	Arduino	1	$ 12.90	$ 12.90
Linear Motor	Prosthetic movement	USLICCX	1	$ 35.00	$ 35.00
Flex Sensor	Sensor for movement	Adafruit	1	$ 12.95	$ 12.95
Soldering Wire	Sauder wired connections	Yi Lin	1	$ 8.99	$ 8.99
Shrink Wrap	Waterproofing wire connections	Wirefy	1	$ 13.99	$ 13.99
9 V Rechargeable Batteries	Motor Power	EBL	1	$ 26.99	$ 26.99
Glue	Wire placement and waterproofing	Gorilla Glue	1	$ 12.33	$ 12.33
Arm Sleeve	Cushion between cuff and forearm	IovyoCoCo	1	$ 13.24	$ 13.24
Liquid Latex	Fingertip grip	TAP Plastics	1	$ 20.75	$ 20.75
Motor Driver	Switches polarity of motor	HiLetgo	1	$ 10.99	$ 10.99
Resistors	Electrical components	Chanzon	1	$ 9.99	$ 9.99
Battery connectors	Increase Voltage for motor	QMseller	1	$ 5.99	$ 5.99
Shipping costs					$ 50
				Cost Total:	$409.78

Total Cost: $409.78

Materials outlined above will be used in testing and prototyping the team's design. If the Flex sensor design is successful a myoelectric design approach may be attempted in Spring 2022 to afford better control of thumb movement based on natural patient muscle activation.

The team will make purchases online with the provided budget. Stephanie Silin will be in charge of making the purchases. For all purchases prior to receiving funding: Stephanie has/will continue to keep all receipts electronic and paper which will be submitted on a rolling basis to the school with contact to Susan Sauer the UW BME accountant. For all purchases after receiving funding purchases will be made through the UW shop purchasing if possible, otherwise receipts will continue to be documented in the same manner as prior to funding.

Conclusions/action items:

I will continue looking into how to improve the design as the team and I await the results of the budget proposal. I hope to get the materials ordered as fast as possible so that the team and I have sufficient time to fabricate our project.

11/03/21 Budget Proposal Results

KAREN SCHARLAU (kscharlau@wisc.edu) - Nov 27, 2021, 6:37 PM CST

Title: Budget Proposal Results

Date: 11/03/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To document the approved budget and plan out next steps.

Content:

The team has received a budget of $500 from the BME administration. We are very excited that we will be able to build the project. The details are:

1. You have a budget of up to $500.

> 1.1. *Dr. P will set up a MakerSpace account for you. It will take a couple of days.*
> 1.2. *The grant will not pay for the $50 shop fee so you'll have to sort that out among yourselves, e.g., split it 4 ways.*

2. Since BME is paying for things you have to use ShopUW+ (or the MakerSpace) to order materials / supplies.

> 2.1. *A list of suppliers can be found here: https://shopuwplus.wisc.edu/suppliers/*
>
> *Suppliers – ShopUW+ Essentials – UW–Madison*
>
> *Airgas distributes industrial, medical, and specialty gases, welding supplies, safety products and tools. This is the place to look when ordering your gas cylinders.*
>
> shopuwplus.wisc.edu
>
> 2.2. *Dr. P will need a complete list of materials following the BPAG guidelines (e.g., part numbers, vendor links, quantities, etc.)*
> 2.3. *Then Dr P./assistant will place the order to ship to the ECB for you to retrieve.*

Conclusions/action items:

I will get to work right away with finalizing how the money will be used. I will need to look through all of the websites to check if any of our products can be bought through pre-approved websites. I will create a document that keeps track of what I was able to find and share it with the team and Mitch.

11/05/21 Waterproofing Circuits

KAREN SCHARLAU (kscharlau@wisc.edu) - Nov 29, 2021, 12:47 PM CST

Title: Waterproofing Circuits

Date: 11/05/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To figure out how to waterproof the circuits that will be on the prosthetic hand so that rain is not a problem for the patient.

Content:

I will be exploring different ways of waterproofing electronic components with different materials and methods.

- Nail Polish
  - Can be painted on a circuit board
  - Very cheap
  - Not durable
  - Not heat or wear resistant
  - Once it is on, cannot make changes
- PCB Varnish
  - Easy to apply spray
  - won't crack
  - Can be soldered through, which means you can make changes to the board after application
- UV curable soldermask
  - temperature resistance
  - good adhesion
  - inexpensive
  - Need a UV flashlight
  - Fast hardening
  - thin layer that works best on flat surfaces
  - Best for small parts of boards, not entire boards
- Clear Silicone Adhesive
  - good adhesion
  - temperature resistant
  - soft

Out of these options, the PCB Varnish seems to be the best option.

https://www.instructables.com/How-to-Waterproof-Your-Electronics-or-PCBs/

Voltlog and Instructables, “How to waterproof your electronics or PCBS,” *Instructables*, 11-Apr-2019. [Online]. Available: https://www.instructables.com/How-to-Waterproof-Your-Electronics-or-PCBs/. [Accessed: 29-Nov-2021].

Conclusions/action items:

I will inform the team of the different materials I learned about and which I think is best. I will also go to the makerspace and ask about methods or materials that they use. It is best to have something durable that is easy to apply so that the design has the potential to be manufactured on a larger scale.

11/6/21 Attaching a Motor to Arduino

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:42 PM CST

Title: Attaching a Motor to Arduino

Date: 11/6/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To understand the interface between an arduino and the linear motor better.

Content:

There are many videos on youtube outlining how other people attached their motors to an arduino microcontroller. The schematics shown in the videos were very helpful. For the power supply, I found out that the motor the team wants to get runs on 12 volts. I plan to attach to 9 volt batteries together along with a voltage divider to power the arduino and the motor.

https://www.youtube.com/watch?v=I7IFsQ4tQU8&ab_channel=HowToMechatronics

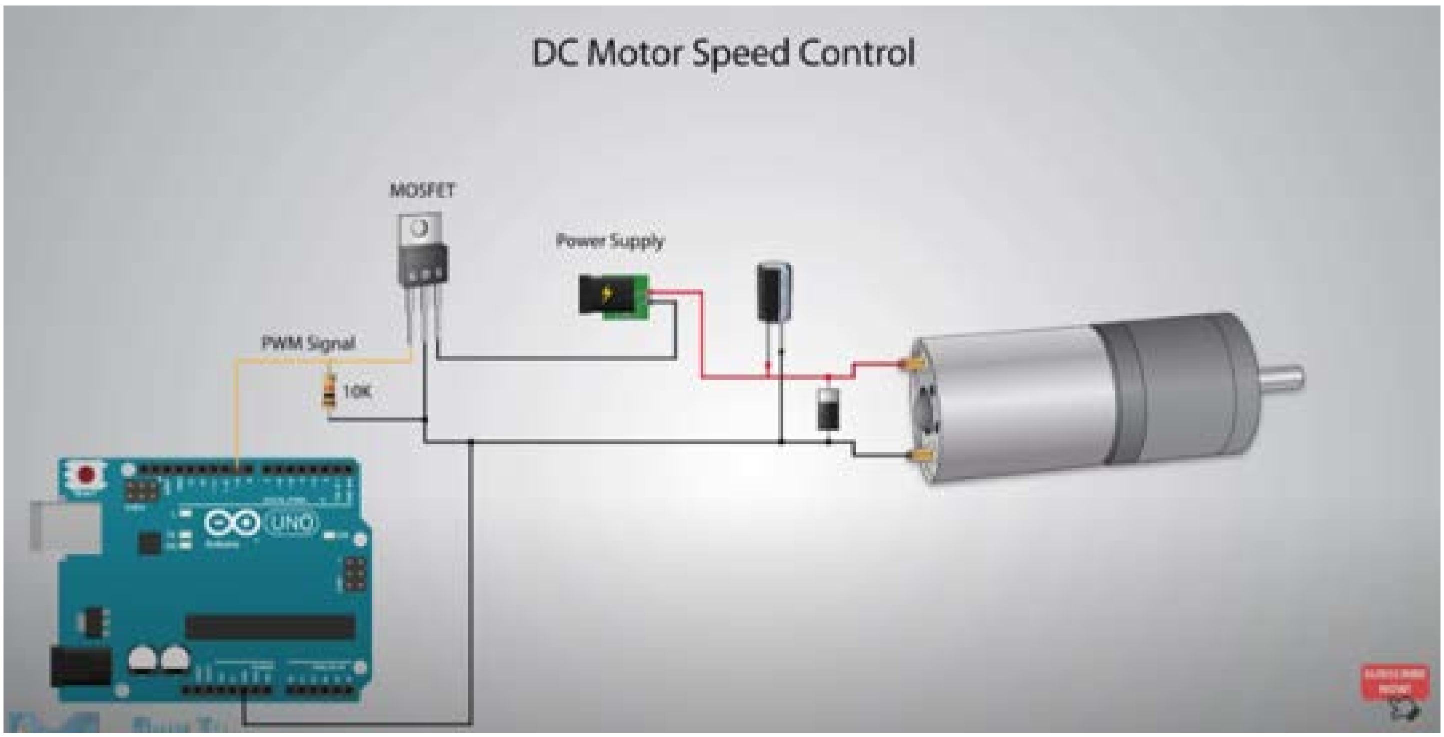


Figure 8: A schematic of an arduino interfaced with a DC motor.

"Arduino DC Motor Control tutorial - L298N - youtube." [Online]. Available: https://www.youtube.com/watch?v=I7IFsQ4tQU8. [Accessed: 06-Nov-2021].

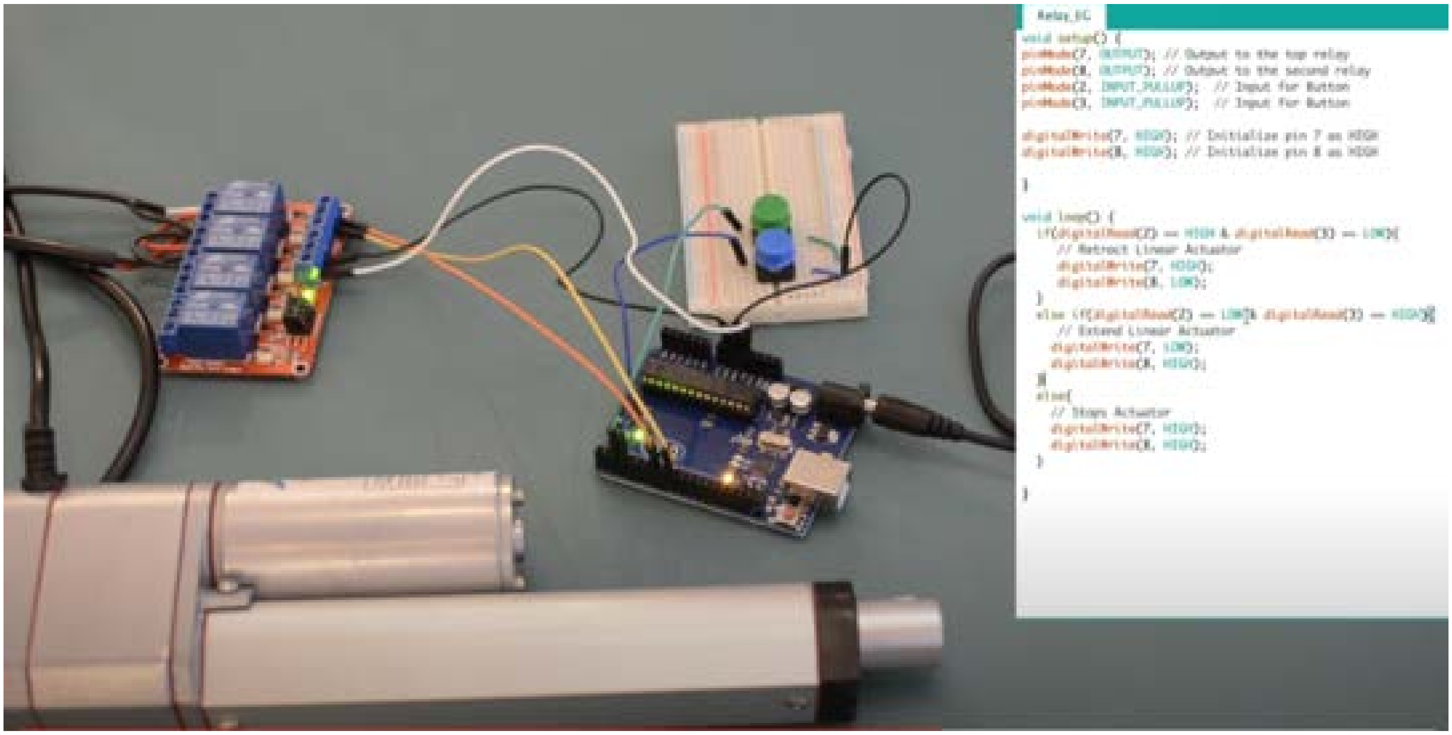


Figure 9: A linear actuator hooked up to an arduino, a relay, and a bread board, along with the code to run it.

I didn't know that the team would need a relay in order to run the linear actuator. The way that a linear actuator works is that with one polarity, it pushes out, and with the opposite polarity, it pulls in. The role of the relay is to switch the polarities of the motor as needed. The code will also be very useful to reference when we are building our own code with the flex sensor.

“Controlling a Linear Actuator with an Arduino and Relay.” [Online]. Available: https://www.youtube.com/watch?v=J1VMrT2P0Ac&ab_channel=FIRGELLIAutomations [Accessed: 06-Nov-2021].

Conclusions/action items:

I will tell the team what I learned about the electronics. I will also add the relay shown in the video to the budget proposal so that the team can control the motor correctly when it arrives.

11/10/21 Limiting Voltage

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:43 PM CST

Title: Limiting Voltage

Date: 11/10/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To explore the possibility of using two 9 V batteries to power both the arduino and the linear actuator.

Content:

The goal of the project is to make a prosthetic that the patient can move around with, so power to the device needs to be small, lightweight, and mobile. The arduino runs on 5V of power, and the linear actuator runs on 12V of power. This adds up to 17V of power total. Two 9V batteries can provide 18V of power. Two 9V batteries will be small, compact, light, and mobile. They meet the team's criteria, but I want to know that the team will be able to split up the voltages correctly. I have taken some electronics classes in the past and have worked with voltage dividers, so maybe a variation of a similar circuit design will help us get what we need.

Along with the batteries needing to physically work in the circuit and for our purposes, we also need the batteries to be cost-effective for the patient, since he is low-income, uninsured, and unemployed. We do not want to put an expensive burden on him and force him to constantly buy 9V batteries in order to use his arm. Those costs will add up, and I want to make sure we don't put an extra burden on him. For this reason, I think that rechargeable batteries would be the best option. This way they can be reused over and over again.

I did some reasearch with the source below for some more information on the electronic aspect of the project:

- Voltage Limiter: a circuit that limits the output voltage
  - This could be useful to the team because we have 18V but only need 17V. I don't think that we want to supply more voltage than needed.
  - There are many different types of limiters that the team could use depending on what is needed. Some examples are unipolar, bipolar, soft, hard, single, or double.

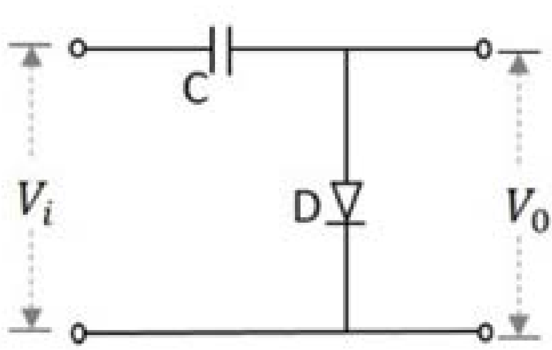


Figure 10: An example schematic of a limiter circuit.

- There are also voltage doublers. This would be very useful, unfortunately, it looks like it is only for AC current, and the team's batteries and linear actuator are both DC.
- A voltage divider has the ability to divide the voltage. This is applicable to the team's uses.
  - The equation is Vout = (Vin*R2) / (R1+R2)
  - It looks like the voltage divider splits the current equally, which is not what the team needs. This topic may require more research.
  - The set up is shown below:

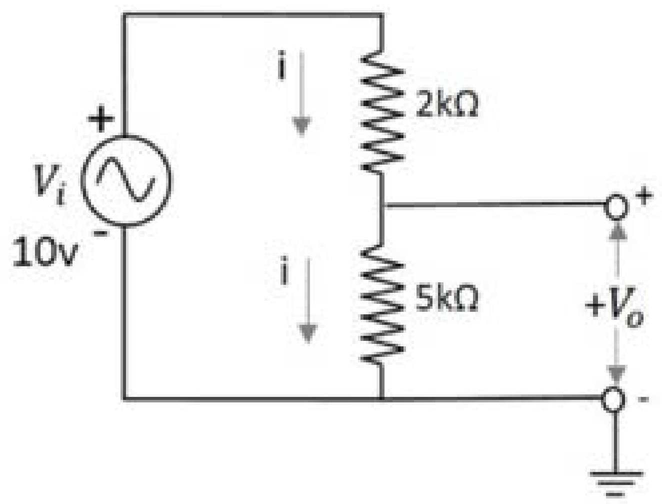


Figure 11: A voltage divider schematic example.

Source:

"Limiter and Voltage Multiplier," *Limiter and voltage multiplier*. [Online]. Available: https://www.tutorialspoint.com/electronic_circuits/electronic_circuits_limiter_voltage_multiplier.htm. [Accessed: 13-Dec-2021].

Conclusions/action items:

This research has shown promis for using two 9V batteries to power the prosthetic hand. I will tell the rest of the team about the different types of circuits that may help us and ask for any ideas that they may have. The 9V batteries are on the budget proposal, so when the supplies come, the team should be able to build and test a circuit for the prosthetic hand. It is also an important consideration that 9V batteries are standard and can be found at any place that sells batteries. If the product design the team makes would ever be built on a larger scale, consumers would have no trouble aquiring 9V batteries.

11/13/21 Thumb Pins

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:43 PM CST

Title: Thumb Pins

Date: 12/13/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To find better pins for the mechanical thumb design.

Content:

The 3D printed pins that the team is currently using will not withstand long term use and cause too much friction. I want to find the team better options. While I was at my internship this summer, I was designing various parts. The company used the website McMaster Carr to find a wide array of parts. I knew they would have pin options there, so I took a look. After browsing the site, I finally found some pins that I think will work great. They are called Clevis pins. They have stops on both sides, are made of stainless steel, and are easily removable. These are all very important aspects because we want them to be strong, hold the pieces together, and we also want them to work for various designs.

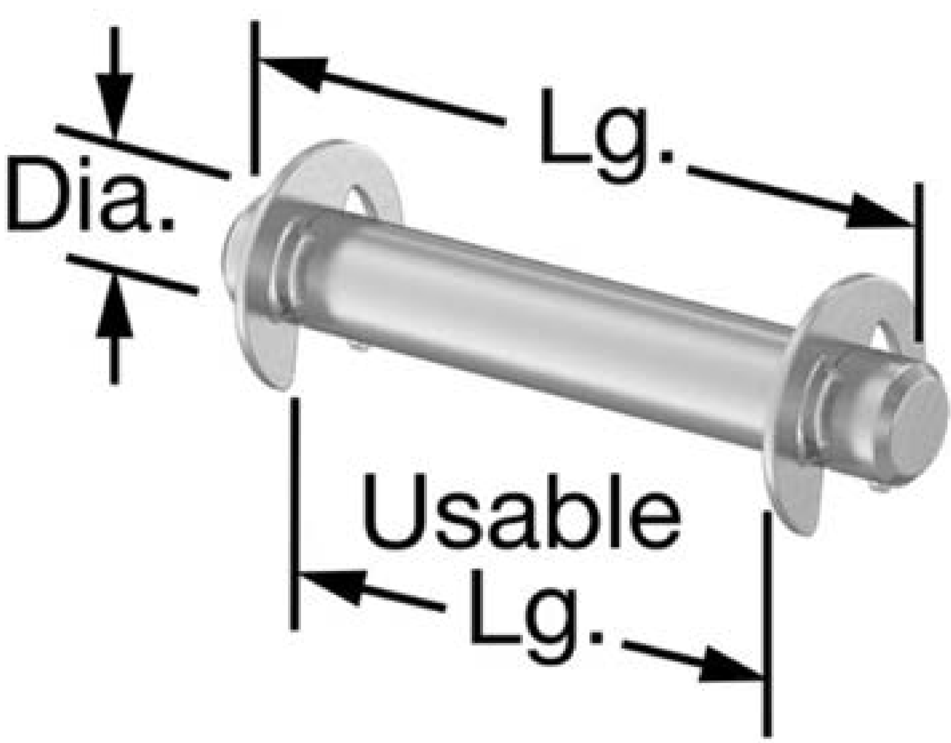


Figure 13: Headless Clevis Pin that will allow for easy and strong pinning of joints in the prosthetic thumb design.

https://www.mcmaster.com/93890A701/

"Carr," *McMaster*. [Online]. Available: https://www.mcmaster.com/93890A701/. [Accessed: 13-Dec-2021].

Conclusions/action items:

This pin will have less friction, more strength, and more versatility than the 3D printed pins the team is currently using. I will send the picture of this pin to my team and see what they think of my idea. If they agree that it is the best option the team has, I will add it to the budget justification. These are also very generic parts that are cost-effective and easy to get in case more projects based off of this design are needed.

11/16/21 Thumb Grip

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 13, 2021, 6:02 PM CST

Title: Thumb Grip

Date: 11/16/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To find a stronger thumb gripping material than liquid latex.

Content:

Liquid latex is used in the make-up industry to look like skin. While this is great for appearance purposes, I don't think that it will be strong enough to provide sufficient grip in our design. I have used flex seal in the past on a different BME project. It was used to coat plastic wheels on a toy car to provide more grip. It was successful, sturdy, and grippy. While the team does ultimately want the thumb to look as natural as possible, I do not want to sacrifice functionality. Based on what the client has communicated, function is more important in our design.

Conclusions/action items:

I will propose to the team that we use flex seal for grip instead of liquid latex. If the team decides flex seal is the better option, I will add it to the budget justification.

11/17/21 Budget Justification

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:45 PM CST

Title: Budget Justification

Date: 11/17/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To document the budget justification.

Content:

I created a preliminary budget justification and sent it to Mitch. He had a lot of really good comments on how to make it better. I included the links to all the products so that there would be no confusion on finding the correct product. I was also able to find a lot of products at the makerspace.

Budget Justification:

Materials Request and Justification

Prosthetic Hand Project

BME 400

Emmalina Groves, Stephanie Silin, Danielle Lefko, Karen Scharlau

Faculty Advisor: Mitchell Tyler

The funding provided to the prosthetic hand project is greatly appreciated. The websites provided through Shop UW, however, are unsatisfactory, and consequently have caused a setback. With only a few remaining weeks for the project to be completed, the team needs to order all the materials as fast as possible to be able to complete fabrication and testing of the prototype. The linked websites at Shop UW do not provide sufficiently small volume or specific type of materials for the scope of the project. Specifically, many of the websites require bulk ordering, which is wasteful. The remaining websites do not have the specific products that the team requires to build the design. The design will help the patient to return to work and regain control in his right hand, but this cannot be done if the materials cannot be purchased.

1. Items that were found on ShopUW but do not work for the project

1. Rechargeable Batteries
    1. Found at Buy on Purpose: Price: 4 batteries + charger = $109.97
    2. Alternate supplier: 4 batteries + charger = $24.45
    3. Rechargeable batteries are essential to the design for powering the linear motor and controller in the prosthetic device. The alternate supplier is considerably more affordable. The team would like to buy the batteries from an alternative source to save money for other parts of the project.
2. Arm Sleeve
3. Found at Fastenal
4. The minimum order from Fastenal is 144 units which costs $1451.52. The team only needs one arm sleeve. The total cost for this component alone is almost 3 times the provided budget.

1. Products to be ordered from ShopUW:

Table 3: Products that can be ordered from ShopUW.

Item	Link	Manufacturer	Quantity	Price	Total
Glue	https://www.buyonpurpose.com/Products/Clear-Gorilla-Glue--175-oz--Dries-Clear__GOR4500101.aspx?ix=1&fc=SR&tht=k&thp=3	Buy On Purpose	1	$ 10.13	$ 10.13
Closed Cell	https://www.grainger.com/product/GRAINGER-APPROVED-Water-Resistant-Closed-Cell-39G038	Grainger	1	$18.80	$18.80

Foam						
Velcro Ties	https://www.buyonpurpose.com/Products/ONE-WRAP-Pre-Cut-Thin-Ties--05-x-8--BlackGray--50Pack__VEK90924.aspx?ix=8&fc=L3C&pq=velcro	Buy On Purpose	1	$5.79	$5.79
Clevis pins	https://www.grainger.com/product/GRAINGER-APPROVED-Stainless-Steel-Clevis-Pin-2XAC2	Grainger	10	$1.66	$16.60
			Total:	$ 51.32	$ 51.32 + Shipping

1. The remaining items were not available through shopUW and are integral to the project.

Table 4: Products that cannot be ordered from ShopUW.

Item	Description	Manufacturer	Link to Product	Quantity	Price	Total
Arduino Nano Every	Microcontroller	Arduino	https://store-usa.arduino.cc/products/arduino-nano-every	1	$ 12.90	$ 12.90
9 V Rechargeable Batteries	Motor Power	EBL	https://www.amazon.com/EBL-Batteries-Rechargeable-Battery-Charger/dp/B00HV4KFSA	1	$ 26.99	$ 26.99
Arm Sleeve	Cushion between cuff and forearm	IovyoCoCo	https://www.amazon.com/Protectors-Resistant-iSbaby-Protection-Abrasion/dp/B07WDKWZQF/ref=sr_1_5?dchild=1&keywords=silicone+forearm+sleeve&qid=1635727023&sr=8-5	1	$ 13.24	$ 13.24
Flex Seal	Fingertip grip	Flex Seal	https://www.amazon.com/RESPONSE-LFSGRYR16-Flex-Seal-Liquid/dp/B01GFY9X3E/ref=sxin_15_ac_d_rm?ac_md=3-3-ZmxleCBzZWFsIGxpcXVpZA%3D%3D-ac_d_rm_rm_rm&cv_ct_cx=flex+seal&keywords=flex+seal&pd_rd_i=B01GFY9X3E&pd_rd_r=b18145c6-c29e-477d-9d01-800ed24dbc51&pd_rd_w=19qRi&pd_rd_wg=b2uYZ&pf_rd_p=c41d1f6c-956c-4fe2-8019-1663b7e1dd23&pf_rd_r=XR6Y1JPZDK1ENXZF42D8&psc=1&qid=1637345784&sr=1-4-12d4272d-8adb-4121-8624-135149aa9081	1	$ 14.99	$ 14.99
Motor Driver	Switches polarity of motor	HiLetgo	https://www.amazon.com/HiLetgo-BTS7960-Driver-Arduino-Current/dp/B00WSN98DC/ref=pd_rhf_dp_s_crs_dp_rhf_k2p_5/141-3892616-7280859?pd_rd_w=745aH&pf_rd_p=19a9e137-bc31-4586-82ad-83470df686c4&pf_rd_r=G6Q0VKERDBQPT49XQGN4&pd_rd_r=8ae291ac-a222-430a-88be-52d69418d3e0&pd_rd_wg=eRgao&pd_rd_i=B00WSN98DC&psc=1	1	$ 10.99	$ 10.99
					Cost Total:	$79.11 + Shipping

Conclusions/action items:

I will email John Puccinelli a copy of this budget proposal in hopes that he will order the materials listed. While I wait, I will continue research on the rest of the project. It is important for us to be working on different parts of the project simultaneously so that we can get everything done on time. Since we can't go any further on the budget/ordering materials, we should turn to other tasks that can be done.

11/29/21 Thermoforming Machine

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:48 PM (

Title: Thermoforming Machine

Date: 12/13/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To figure out if thermoforming the forearm cuff is a viable option.

Content:

The makerspace has a thermoforming machine that has the ability to mold plastic to odd shapes. The patient's forearm is unique, and the cuff must fit tightl on his forearm. This option would allow us to create a custom fit. I am worried about the plastic's sturdiness, however. Only certain types of plastic can be u in the thermoforming machine. To find out more, I visited the makerspace and talked to one of the workers certified to use the thermoforming machine. I fou out from them that you can thermoform around clay, wood, or PVC plastic. The plastic that they use in the thermoformer is polystryene. After looking at the options, I do think that this method will be the best for fabricating the cuff.

Figure 14: An image of the thermoformer machine at the Makerspace on the UW-Madison campus.

This is the machine the team could use to create the forearm cuffs.

Figure 15: An example of what the thermoformer machine can make. This part has curves and edges on it, and the plastic is sturdy.

The plastic from the thermoform machine felt sturdy, and looked like it could be molded around any shape. I think this is an extremely promising method fo fabricating the forearm cuff.

Conclusions/action items:

I will send these pictures and information to the team to let them know that I found a very promising method for creating a custom forearm cuff. I know that mold of the forearm will be needed to create the cuff, so I will email the client to ask for pictures and measurements of the forearms so that the model we m will fit the patient well.

11/30/21 Mechanical Thumb Design

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:50 PM CST

Title: Mechanical Thumb Design

Date: 11/30/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To design a working mechanical thumb that can attach to the linear actuator.

Content:

I spent many hours adjusting each aspect of the thumb I created in solidworks. Here is the final result.

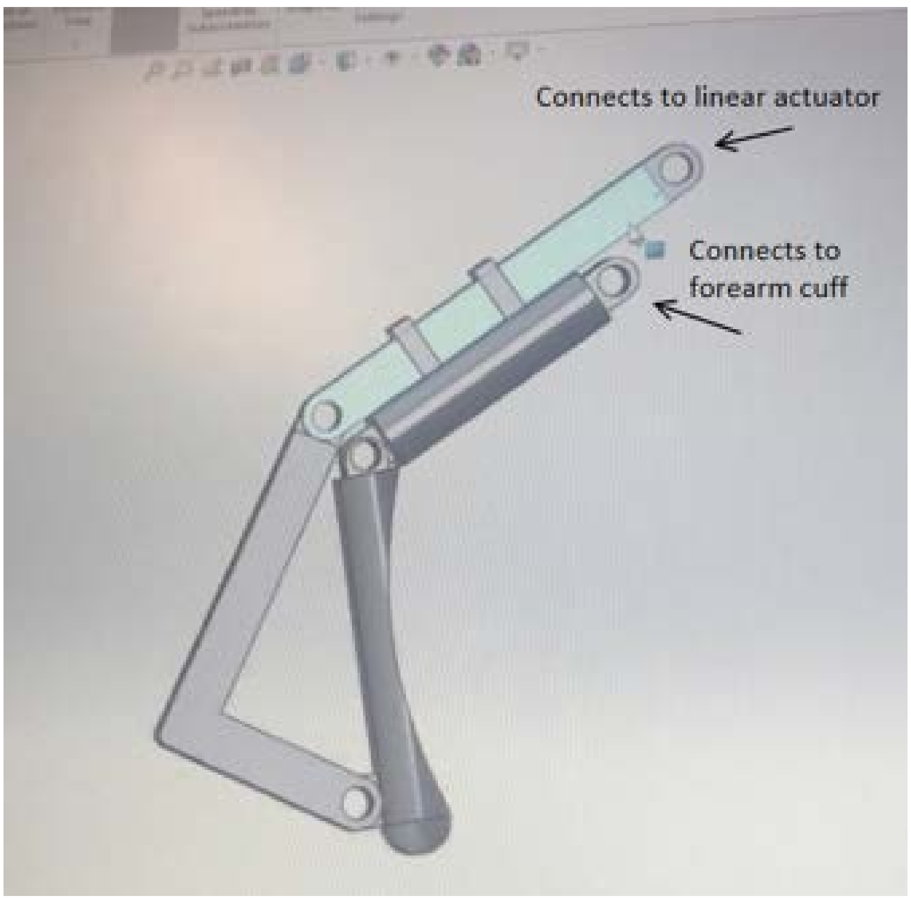


Figure 16: Model of thumb mechanism that moves with linear motion.

Features Designed into the model:

- Curved gripping surface that would be coated in flex seal for maximum grip.

- Area on gripping side clear of any bulky parts

- Range of motion depends on how far the motor moves in and out, so it is very adjustable to the client.

Conclusions/action items:

I will print this design so that I can see how it works in the real world and run some tests to compare it to the current design. I will also send the files of this design to the rest of the team and offer to take feedback and improve the design.

12/1/21 Forearm Cuff Manufacturing

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:51 PM CST

Title: Forearm Cuff Manufacturing

Date: 12/1/21

Content by: Karen Scharlau

Present: Karen Scharlau and Emily Groves

Goals: To create the forearm cuff portion of the project.

Content:

After talking to the makerspace employees, we formed a plan for fabrication:

1. Build the model forearm
    1. Find a base material to give structure to the mold
    2. Mold clay around the base material to look like the patient's forearm. Use pictures and measurements to ensure accuracy.
2. Warm up the thermoforming machine
    1. The heating element of the thermoformer must heat up. This takes about 15 minutes.
3. Buy 1/8" polystryene material
    1. 1/8" polystryene is a very sturdy plastic that will work well for the cuff
4. Set the model forearm into the thermoforming machine
5. Load the polystryene plastic
6. Wait for the polystryene plastic to warm up
    1. When the plastic is sufficiently warm, it should droop in some places
7. Pull the lever to push the mold up into the plastic
8. Activate the vacuum
    1. Push the vacuum button until the plastic is sufficiently pulled around the details of the mold
    2. Don't hold this too long or the plastic could rip.
9. Let the plastic cool and remove the mold.
10. Repeat steps 1-9 on other side of the mold
11. Cut out the cuffs using the band saw
12. Sand the cuffs down to the desired size

The base material that we chose was wood because it was readily available in the scrap area of the makerspace. We glued two 1/2" x 1" x 10" pieces of plywood together to get the desired base shape. We could not go further on this until the clear gorilla glue cured.

Figure 17: Base material of plywood being glued so that clay can be formed around it.

Conclusions/action items:

Check that the glue cured tomorrow, and make the mold out of clay. Then, follow the rest of the Fabrication plan steps. I will note any deviations from the fabrication plan and update it as necessary.

12/2/21 Cuff Manufacturing Pt. 2

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:52 PM

Title: Cuff Manufacturing Pt. 2

Date: 12/2/21

Content by: Karen Scharlau

Present: Team

Goals: To creat the forearm mold.

Content:

The forearm mold was created and measured. A makerspace worker certified to use the thermoformer was not present, however, so the forming could not take place yet.

Figure 18: An image of the formed mold that will be used to create the cuff.

Conclusions/action items:

I checked with an employee and set up a time tomorrow that I can thermoform with a certified employee. I will update the team accordingly.

12/3/21 Thermoforming the Cuff

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:53 PM (

Title: Thermoforming the cuff

Date: 12/3/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To form the plastic to the mold in order to create the cuff.

Content:

I bought two sheets of 1/8" polystyrene from the makerspace after setting up the thermoformer to start warming up. Once the machine was warmed up, I se the mold of the forearm into the machine so that the "top" of the forearm would get molded. Then the plastic was loaded in, and I waited a couple minutes fo to heat up. It started to droop in various places, which told me and the makerspace worker that it was ready. I pulled the lever that pushes the mold into the plastic, then pushed the vacuum button. I waited for the plastic to pull around the mold, then stopped the vacuum function. I waited for it to cool, then pulled out the mold. The heat of the plastic melted the clay a little bit, so I went and remolded the forearm mold. I measured to make sure it was the same as befor then brought it back and repeated the same thing on the other side so that I had two sheet of molded plastic. Stephanie and Danielle showed up and helpe cut out and sand the molds I made. Then, after looking at the sizing of the cuffs, I sanded off more material from the cuffs.

While I was waiting for the thermoformer machine to heat up, I sewed a sweatshirt sleeve that I found from the scrap bin of the makerspace into a sleeve th could house the flex sensor and fit underneath the forearm cuff.

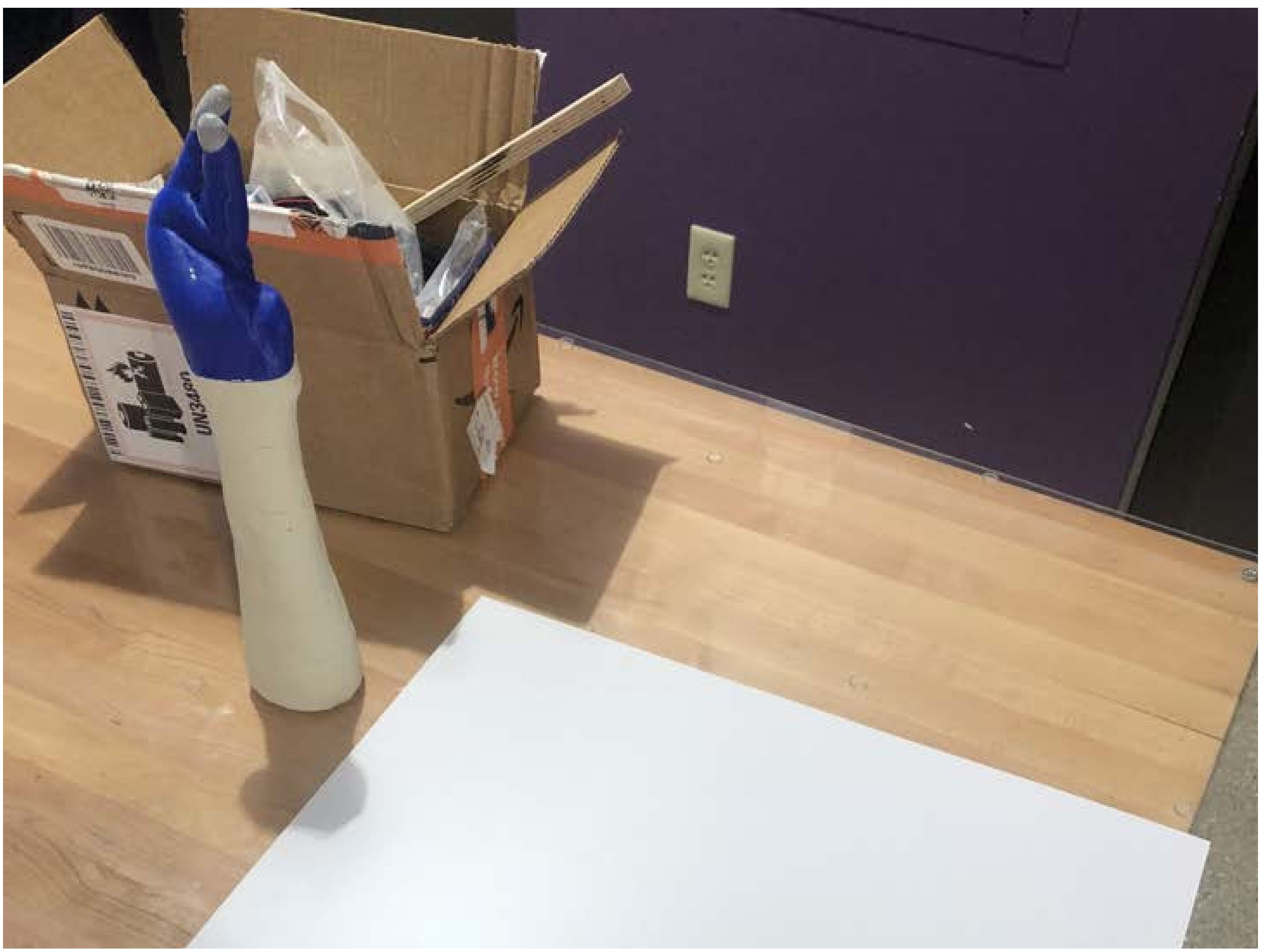


Figure 19: The forearm mold pictured next to the sheet of polystyrene plastic used to mold the cuff.

Figure 20: A picture of the sleeve that I sewed that will be placed underneath the forearm cuff.

Figure 21: The polystyrene plastic after being molded in the thermoformer, but before being cut.

Figure 22: The two cuff pieces after initially being cut out.

Conclusions/action items:

The cuff pieces are sturdy and look great. I am happy with how they turned out. I will velcro the cuffs together later to show that they fit together.

12/4/21 Attaching Cuff pieces together

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 13, 2021, 6:28 PM CST

Title: Attaching Cuff pieces together

Date: 12/4/21

Content by: Karen Scharlau

Present: Karen Scharlau

Goals: To form a hinge on the cuff so that it can be closed using one hand.

Content:

I found a piece of scrap nylon material at the makerspace. It was very strong, yet bendable. I thought it would make a great joint on one side of the cuff. It would also prevent pinching. I glued the nylon onto the two cuff pieces and waited for it to cure. After checking on it later in the day, it turned out great, offering flexibility and strength in one simple joint. The other side will be joined together by velcro straps.

Conclusions/action items:

I will show the team the hinge that I made. I will also begin trying to print out my mechanical thumb design to test it.

12/8/21 3D mechanical thumb testing

KAREN SCHARLAU (kscharlau@wisc.edu) - Dec 15, 2021, 1:54 PM (

Title: 3D Mechanical Thumb Testing

Date: 12/8/21

Content by: Karen Scharlau

Present: Emily, Stephanie

Goals: To determine the best printed part to include on the design.

Content:

Three different designs made by stephanie, emily, and I were 3D printed and assembled. Here are my thoughts on my design:

My (Karen's Design)

- This design won't work at this time because the pin holes are too small for the clevis pins that we have. There is not enough time to reprint since our last p failed and pushed us out another day

-I like this design because it has a large range of motion, it has a curved grip area, and it does not have any mechanical parts that could get in the way of holding things

While the pins did not fit in my design, I created small velcro straps to test the function of my design, and it was able to move in the motion intended.

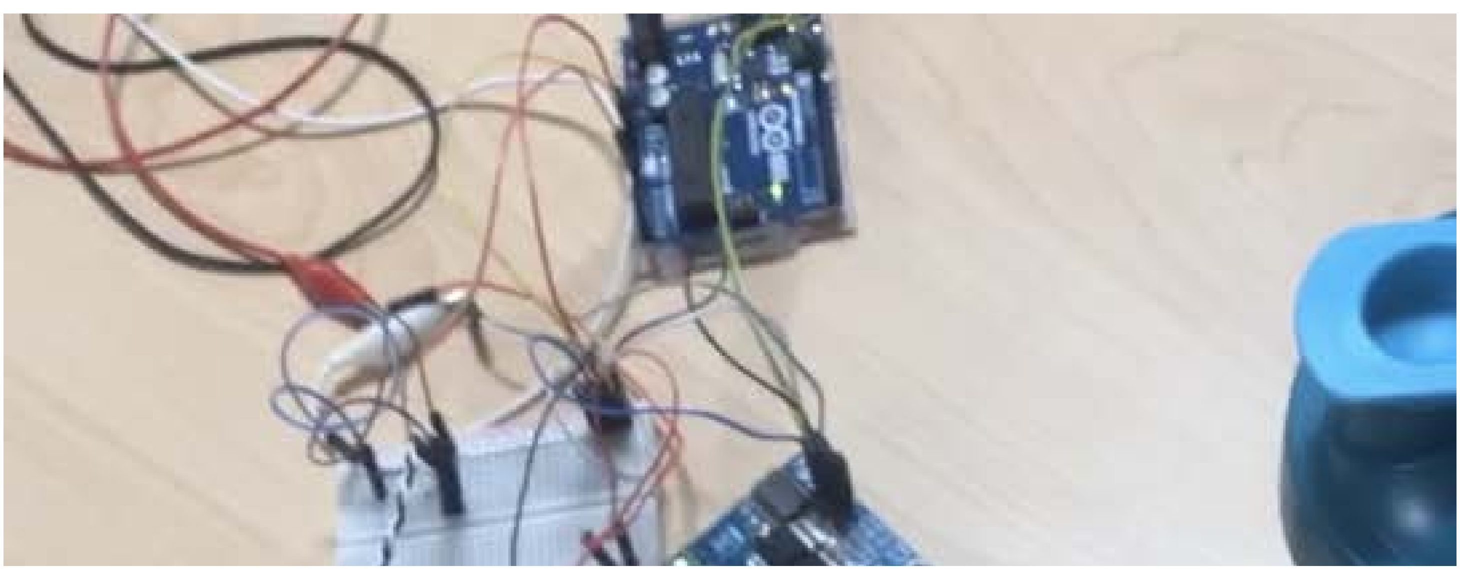
We went with emily's design after analyzing it mainly because it functioned the best. After choosing the design, we hooked it up the the electrical flex senso test it in action. We were able to pick up a small playdough container, and the thumb had consistant flexion.

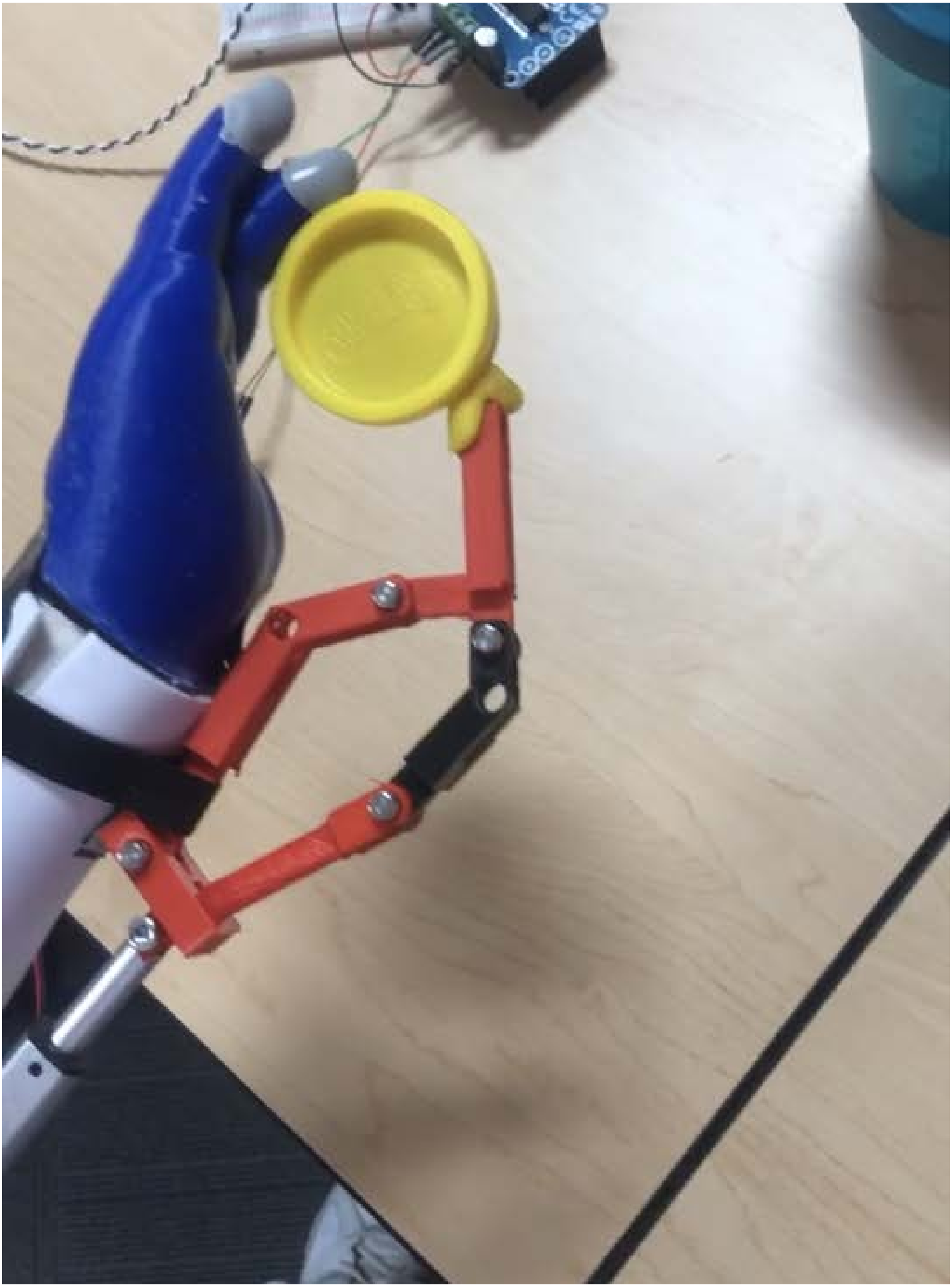
We also measured the grip range in terms of distance. I measured the smallest grip to be 7 cm and the largest grip to be 13cm from the printed pinky. Thes measurements do need to be taken with a grain of salt because the pinky we had cannot move, but the patient's pinky will be able to, so some of the gap w be closed when it is actually on the patient.

Figure 23: Final working prototype of the prosthetic thumb.

Figure 24: Measuring the range of motion of the prosthetic thumb.

Figure 25: 3D Printed Design of my design using velcro clasps because the pins did not fit.





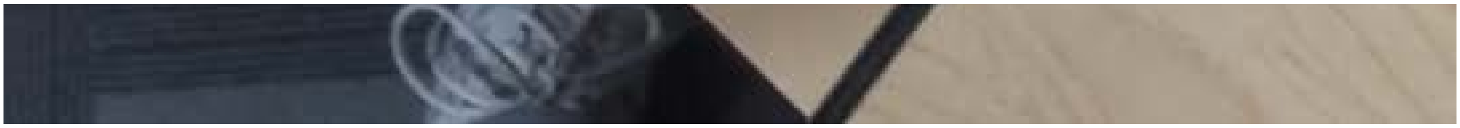


Figure 26: Action shot of the prosthetic hand picking up a playdough container.

Conclusions/action items:

Emily's design functioned best, so we chose that one. I would like to improve my design for next semester and get the correct pin sizes on it so that it can b tested properly. I will add this information to the poster, print it tomorrow, and present on Friday!

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: