BME Design-Fall 2021 - Matthew Wroblewski
Complete Notebook

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Team contact Information

Matthew Wroblewski - Sep 14, 2021, 9:51 PM CDT

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Project description

Matthew Wroblewski - Oct 19, 2021, 11:26 PM CDT

Course Number: BME Design 200/300

Project Name: e-Nable: Prosthetic Grip Strength

Short Name: e-Nable Grip Strength

Project description/problem statement:

The client has asked the team to modify an existing upper limb prosthetic to increase the cylindrical grip strength of the design. Currently, available professional prosthetic limbs are very expensive. On the contrary, less expensive hands are lacking in various areas. The team's client, Ken Bice, is associated with e-NABLE, a low cost provider of 3D printed prosthetics. e-NABLE is an online global community of volunteers who use 3D printers to make and distribute free/low-cost upper limb prosthetic devices for individuals in need. e-NABLE's open source design library allows users to access and modify existing designs to make improvements, allowing for frequent changes to the best designs recommended by the group. The goal for this project is to modify the existing *Phoenix Reborn* [9] model (Figure 2) currently offered by e-NABLE in order to improve at least two facets of the device's grip strength. The device must be made of materials found at local retailers that are low cost and accessible. Ideas for design modifications are limitless and should not be shelved for lack of anatomical resemblance, granted that they contribute towards the end goal of improving the overall grip strength.

About the client:

Ken Bice is the local chapter founder in Madison for e-NABLE, which was founded in 2017. e-NABLE is a global community of volunteers who use an Open Source library of 3D printable models to create affordable and effective prosthetics for those in need.

2021/09/15-Initial Client Meeting

KENZIE HURT - Sep 15, 2021, 7:24 PM CDT

Title: Initial Client Meeting

Date: 9/15/21

Content by: All team members

Present: All team members

Goals: To meet with the client and ask questions/get answers relating to our project.

Content:

- e-Nable very good for pediatric patients to aid with children with some sort of superior limb prosthetic at an affordable price
    - Allows parents to be able to buy prosthetics as the child grows
- The ones using elastic bands don't have as long of a shelf life due to the elasticity getting old/stretching out over time
- Find a way to increase the grip strength on the prosthetic hands. Particularly the fingers curling in towards the palm either all the way or ~half.
- There is no given strength to really compare to so any improvement would be beneficial
- Plastic wires = 1.75 mm printer filament or even weed wacker cord
    - Can use a wide variety of wires they all have their own benefit
- Can scale the hands however necessary when printing
- Bubblegum/behling wire
    - Aka "Think outside the box"
- "Considerably different to be able to add a lot more force"
- Hold strength v.s grip strength
- Demo hand files not yet online, "Phoenix Reborn Hand" (Black printed pieces are new, skin color is from the original Phoenix hand design.)
    - https://www.thingiverse.com/thing:4940047
- Rubber bands last a week in hot humid areas but elastic strings now
- Have one member take the lead on 3D printing and learn more advanced information (SolidWorks)
- Only testing one force value, instead of trying to report on data that is more inconsequential
- Coke can grip and 1 inch cylinder grip
- Don't print under 125% for print, normal is 140%
- **https://www.facebook.com/BadgerHands.org**
- Figure out a baseline test standard
- Pneumatics or hydraulics a possible option
- Plastic bag pneumatic airbags
- Create balloon type of tube and a mesh tube on the outside that acts like a pneumatic muscle
- Stray away from electronics

Conclusions/action items:

- Start looking for stl files for one of the hands. STL Files of individual parts
- Figure out how and what grip strength to test the strain of the hand.
- Continue researching
- Start brainstorming ideas

2021/11/8 Client Meeting

Matthew Wroblewski - Dec 12, 2021, 1:01 PM CST

Title: Client Meeting

Date: 11/8/2021

Content by: Matthew Wroblewski

Present: Matt, Sam, Max, Alex

Goals: Receive prints from the client and go over our progress so far

Content:

- The team was able to acquire the 4 new phalanx pins that we required, so that we would not have to risk improper upscaling of the parts again and could make sure that they would be the correct size
- The client was able to very for us that the hand that we were using was in fact 150% scale as we had suspected but failed to write down at the first meeting of the year with certainty
- We also learned that the 3D prints for e-NABLE models were typically 40% infill, which allows them to be both strong and lightweight, with negative trends in the longevity and strength of the prototype being seen once the model got above 80% infill.
- Ken also instructed us that the plate for the palm of the hand, while PLA, could also be thermoplastic polyurethane TPU sometimes or even leather so that the surface would be less slippery

Conclusions/action items:

The team will now be able to fully assemble the hand once our prints with PLA and PVA are complete, without worry of the pins not being properly upscaled

2021/09/17-Advisor Meeting 1

KENZIE HURT - Sep 17, 2021, 1:30 PM CDT

Title: Advisor Meeting 1

Date: 9/17/21

Content by: Kenzie Hurt

Present: All team members

Goals: To meet with our advisor and talk about class logistics.

Content:

- Neuro interface devices: thought provoking prosthetics utilizing sensors of all types
- Neuromodulation
- Implanted device for blood pressure uses sensor to measure blood pressure and turns on and off for medication ("hijacks systems in the body")
- Looking at the schedule: PDS due in two weeks
- Preliminary oral presentation graded others just feedback
- Grading rubrics on all deliverables
- Any deliverable, look at rubric beforehand to ensure grading goes smoothly/easy
- Do things early and create a safe space for opportunities to learn

Conclusions/action items:

Start working on the PDS that is due in two weeks. Everyone should be brainstorming ideas/solutions to the problem and continuing research. Start thinking about what skills/certifications we may need this semester to do the project and then learn how to attain them.

2021/09/24-Advisor Meeting 2

KENZIE HURT - Sep 24, 2021, 1:17 PM CDT

Title: Advisor Meeting 2

Date: 9/24/21

Content by: Kenzie Hurt

Present: All team members

Goals: To discuss grading for the course and administrative content.

Content:

- PDS and Design matrix not graded, preliminary presentation will be graded.
- Notebooks are turned in mid semester and at the end of the semester. However, the weighting is different with the final notebook weighted significantly more.
- Make sure peer reviews add up to 7000
- When filling out peer evals go in order of team members listed on the website (kenzie, matt, alex, jaime, shreya, max then sam)
- PDS sets up for the rest of the semester and by using quantitative values you can easily set up experiments quantitatively.
- Get to experiments and building earlier rather than later to give time for learning opportunities and/or any unforeseen problems.
- It's ok to say "this is what we would've done" if we aren't able to do it and document in LA.

Conclusions/action items:

Alex will follow up with Ken and Dr. Puccinelli about our budget. Everyone will start brainstorming ideas for our design matrix and bring those ideas to our next meeting on Monday. On Monday, we will plan to put our ideas together and make our design matrix.

2021/10/01-Advisor Meeting 3

KENZIE HURT - Oct 01, 2021, 4:45 PM CDT

Title: Advisor Meeting 3

Date: 10/01/21

Content by: Kenzie Hurt

Present: All team members

Goals: To go over the PDS, the design matrix for next week and talk about the push back on preliminary presentations.

Content:

- Talked about how to approach the changes the client has been making and to determine what we need to make clear.
- Talked about the PDS: comments on the anthropometric complications
- Oral presentations have been pushed back, upload presentation on website

Conclusions/action items:

Our team would like to meet with the client again or at least send a clarifying email as to what exactly he wants, and what we are trying to emulate in real life situations. From there, we will be able to create our design matrix tailoring to the client's desires, while also putting constraints that consider the timeline of our class.

2021/10/22-Advisor Meeting 4

KENZIE HURT - Oct 22, 2021, 1:18 PM CDT

Title: Advisor Meeting 4

Date: 10/22/21

Content by: Kenzie Hurt

Present: All team members

Goals: To talk about preliminary deliverables aftermath and any questions for future work.

Content:

- Talked about the preliminary presentations and how we did
- Discuss next steps moving forward with our design (fabrication and testing)
- Get a mean and confidence interval for data analysis after testing

Conclusions/action items:

The team will discuss what type of testing we want to do for our project as the testing our client provided us isn't necessarily useful. We will talk about doing both qualitative and quantitative testing and what they may look like in terms of our project. We will begin testing within the next 2 weeks, before then, we will keep working on fabrication to make sure that everything fits and works properly.

2021/10/29-Advisor Meeting 5

KENZIE HURT - Oct 29, 2021, 1:14 PM CDT

Title: Advisor Meeting 5

Date: 10/29/21

Content by: Kenzie Hurt

Present: All team members

Goals: To discuss the show and tell.

Content:

- Grades will be submitted through canvas - on Monday
- Show and tell - still waiting on information on it, in person, but unsure about where it will be and how it's going to work
- Structure of show and tell isn't going to change so follow the guidelines
- Not graded, just an opportunity to get feedback from peers or advisors
- 60s elevator pitch - explain what the project is and the plan and also give a demonstration
- Focus on what you want to get back for feedback
- Split into two groups: one stays to give pitch and the other goes to other projects

Conclusions/action items:

The team will most likely follow up with kip this next week depending on our feedback on our preliminary deliverables. The team will continue to work on fabrication and testing protocols while also shifting our focus to the show and tell.

2021/11/12-Advisor Meeting 6

KENZIE HURT - Nov 12, 2021, 1:16 PM CST

Title: Advisor Meeting 6

Date: 11/12/21

Content by: Kenzie Hurt

Present: All team members

Goals: Talk about mid semester grading/feedback.

Content:

- Talk about the future plans
- Go to rubric on bme website to make sure to get all the criteria in (even if it is a sentence or two)
- Peer evals: make sure to list in order on website, do it as a word document not a PDF, make sure the total adds up to 7000
- For qualitative testing: try to quantify data by standards like 1=not acceptable, 4=great

Conclusions/action items:

The team will be finishing putting the hand together and start writing our testing plans. We will be doing quantitative testing first with with hand dynamometer to test for the crushing force. Our additional qualitative testing will be some form of grabbing different sized/weighted objects and then quantifying it by our clients standards.

2021/12/03-Advisor Meeting 7

KENZ

Title: Advisor Meeting 7

Date: 12/03/21

Content by: Kenzie Hurt

Present: All team members

Goals: Talk about the rest of the semester and the final deliverables.

Content:

- Talked about testing: qualitative testing of picking up different things, then our quantitative testing was testing the strength of the hand using a hand dynamometer
- In a week we are doing the poster session which is in person, but the format is very similar to the online ones we did last year
- Poster session is used to replicate a poster session that would be seen at a scientific conference
- Resources page: guidelines, the outline of the day, where to print the poster (college library is pretty fast), poster outlines
- Same groups as last time, the advisors assigned to us will be going to our presentation and assessing us
- Common first issues: tendency to put too much information on them, make sure text and graphs are going to be readable with people standing a distance away, don't cram too much information that y
- Next week posters are due, the week after the final deliverables are due

Conclusions/action items:

The team will continue working on our posters and final deliverables. We have just finished all of our testing and data collection so we will be analyzing the data and do some statistical analysis on it for our final

2021/09/11-Meeting 1

KENZIE HURT - Sep 11, 2021, 10:50 AM CDT

Title: Initial Meeting with Team

Date: 9/11/21

Content by: Kenzie Hurt

Present: Matthew, Kenzie, Alex, Jaime, Shreya, Sam

Goals: To discuss and assign team roles.

Content:

- Talk about which roles people are interested in and then assign roles.
- Discussed our availability and when we will be able to meet outside of scheduled class.
- Did some research on our client

Conclusions/action items:

Alex will email our advisor and client about scheduling times to meet. All team members will start researching our project and document it in their own labarchives folder. Shreya will create our website and upload our team role assignments and team picture. Kenzie and Matthew will create the first progress report.

2021/09/13-Meeting 2

KENZIE HURT - Sep 13, 2021, 6:45 PM CDT

Title: Progress Report

Date: 9/13/21

Content by: All team members

Present: All team members

Goals: To write our progress report, brainstorm questions for our client, and discuss the general outline of class.

Content:

- https://hub.e-nable.org/p/devices
- https://i.pinimg.com/originals/92/40/c7/9240c7c80f9be980daa42aee985a4a0d.png
- Looked at the different hand/arm designs on the website to come up with questions for our client.
- https://www.youtube.com/watch?v=3ZyDLGgSj60
- Watched above video to gain background and see the prosthetics in action.
- https://bmedesign.engr.wisc.edu/projects/f18/enable_lateral
- Created a list of questions for the client:
    - What is the budget for the final product?
    - Which grips would be most beneficial to improve?
    - What testing data and specifications are currently available?
    - What should be the range for the unit price increase per prosthetic?
    - What types of material are available to use - Printer material and string/cable material
    - What are the current testing procedures?
    - Should the grip increase be a passive increase or require an active modulation via the opposing hand
    - Do the recipients of the prosthetics have any preferred grips they would like improved?
    - What specific issues are customers having with grip strength?
    - Is there a testing device that simulates real life use
    - What should we do if the way to increase grip strength minimizes the simplicity of putting the hand together?
    - Prefer an alteration or an addition to the prosthetics?

Conclusions/action items:

Each team member will conduct their own research and document it on Lab Archives. The team will meet with the client on Wednesday, Sept. 15 and after our meeting we will know more about the logistics of the prosthetic. We will then determine which design and grip strengths we will improve upon.

2021/09/20-Meeting 3

KENZIE HURT - Sep 20, 2021, 7:48 PM CDT

Title: PDS

Date: 9/20/21

Content by: All team members

Present: All team members

Goals: To write our PDS and start brainstorming ideas.

Content:

- We started to write our PDS by everyone taking different parts of the PDS
- We filled out as much as we could with the research that we had
- We talked about how we are going to tackle this week looking at scheduling

Conclusions/action items:

The parts of the PDS that we couldn't fill out due to not having research on it, we will research those parts and document them in labarchives. Looking forward into the week, we will continue research, start brainstorming ideas and maybe start creating brief sketches of our ideas.

2021/09/27-Meeting 4

KENZIE HURT - Sep 27, 2021, 6:43 PM CDT

Title: Design Matrix

Date: 9/27/21

Content by: Kenzie Hurt

Present: All team members

Goals: Discuss everyone's ideas that they brainstormed and then discuss which 3 to move forward with for the design matrix.

Content:

- Using air pressure to conform to the object picking up
- Just the thumb moving using a spring
- Change of material? - foam or plush material that can conform to object (memory foam)
- Increase surface area of the contact of the object
- Cable from thumb to middle finger that is elastic to give more stability - two handed mechanism
- Reverse the tension to the inside of the hand - closed in neutral then flexion of of wrist opens the hand
- Short flexion motion in half with a winch drum
- Move the thumb to the inside center?

Conclusions/action items:

We will work on the design matrix this week and get clarification on what our client wants since information he has presented to us has been contradicting.

2021/10/01-Meeting 5

KENZIE HURT - Oct 01, 2021, 4:50 PM CDT

Title: Group Meeting 5

Date: 10/01/21

Content by: Kenzie

Present: Most team members

Goals: To discuss the outline for this upcoming week and the design matrix.

Content:

- Chose our three designs for our design matrix that would fit the needs of the problem
- Discussed another addition to one of our designs that may improve the curvature of the grip strength
- Decided on how we wanted to do our design matrix i.e. what categories we will be considering for criteria

Conclusions/action items:

The team will work on the design matrix and have it completed by Sunday night. Kenzie and Matt will update the team on our plan to go about the design matrix and our designs for the semester.

2021/10/04-Meeting 6

KENZIE HURT - Oct 04, 2021, 6:31 PM CDT

Title: Preliminary Presentation

Date: 10/04/21

Content by: Kenzie Hurt

Present: All team members minus Alex

Goals: Begin 3D modeling, think about fabrication and start the preliminary presentation.

Content:

- We started to make our outline for the preliminary presentation
- Sam started fabricating the extra phalange for our design that we are moving forward with on solidworks
- We took apart the prosthetic we had in order to get the dimensions for the extra part

Conclusions/action items:

Finish the preliminary presentation, start thinking about how we are going to fabricate the designs and think about how we are going to test our designs to see if it has been improved.

2021/10/18-Meeting 7

Title: Preliminary Deliverables

Date: 10/18/21

Content by: Kenzie Hurt

Present: Matt, Kenzie, Sam, Max, Shreya, Jaime

Goals: To split up the preliminary report to assign who is doing what part of the report.

Content:

- We started by just talking about how this week is going to go and updates on everyone's lab archives entries
- Everyone looked at the outline for the preliminary report and decided what parts they would best be able to write
- Everyone was assigned a couple parts to the preliminary report tailoring to what parts they are best suited for and obtained any information from other team members if needed

Conclusions/action items:

The team has decided to have everyone get their parts written by tomorrow (Tuesday the 19th) at 6pm in order to then proofread and fix any mistakes by the end of the night. We plan to submit the preliminary r
may meet tomorrow to proofread together, but it is more likely that with everyone's schedules that we will just proofread on our own.

KENZIE HURT - Oct 25, 2021, 6:45 PM CDT

Thermoplastic Material

Secondary Tensioning (Pulleys)

Secondary Tensioning (No Pulle kys)
Running a second wire over the back of the hand to grip the

Bigger Holes
Anchor wire to back of redesigned apriot piece with a hole going towards the tip of the finger then a channel going down towards the bar anchor which is now a wall.
Longer top back part to prevent hyper extension

Print 2 more old middle phalanx
Print 4 u[pdated middle phalanx
Print 4 tips
4 small pins

For next week.... Nov 1
Sam update existing model part
begin work on new part

During Next week....nov 1 through 7th
Print new red parts and assemble all 4 to hand (4 pins 4 phalanges)
Finish new part
Testing protocol

For 2 Weeks from now.... Nov 8
Testing protocol
Printed new parts (4 tip fingers)
Test original hand and then new updated hand....sometime in future or on day

Fabrication_Matrix.pdf(51.2 KB) - download

2021/11/29-Meeting 8

KENZIE HURT - Nov 29, 2021, 5:14 PM CST

Title: Final Deliverables

Date: 11/29/21

Content by: Kenzie Hurt

Present: Matt, Kenzie, Sam, Max, Shreya, Jaime

Goals: To catch the team up/updates and talk about the plan for the rest of the semester.

Content:

- Matt and Kenzie updated the team on where we are at for progress this semester.
- We made a plan for the rest of the semester.
- We discussed when we are going to do our second form of testing with the dynamometer.

Conclusions/action items:

Matt, Sam, Kenzie and maybe one more person are going to test the two hand designs with the hand dynamometer at the physiology lab on Thursday. Then we will be doing data analysis on our testing. Throughout the next two weeks, we will be working on our final report and poster presentation.

2021/9/24 PDS

Matthew Wroblewski - Oct 19, 2021, 11:36 PM CDT

Title: Product Design Specifications

Date: 2021/09/24

Content by: Matthew Wroblewski

Present: The Team

Goals: Create and Upload the PDS

Content:

See attached

Conclusions/action items:

We will submit this to our advisor and wait for feedback before moving forward in the design process. This document will also be referenced throughout the design process.

Matthew Wroblewski - Oct 19, 2021, 11:36 PM CDT

e-Nable Prosthetic Grip Strength - BME 300/200

Product Design Specifications

September 24, 2021

Section 306

Client:	Ken Bice	ken.bice@gmail.com
Team:	Matthew Wroblewski	mdwroblewski@wisc.edu
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	Sara Strachan	sstrachan@wisc.edu
	Jaime Barajas	jdbarajas@wisc.edu

Function: The client, Ken Bice, has requested that the function of the e-Nable *Phoenix Reborn* 3D printable prosthetic hand be altered to achieve an increased capability of cylindrical grip strength. Current models of prosthetic hands provided by e-Nable are very limited in their ability to grasp cylindrical objects smaller than a soda can, approximately 6.6 cm in diameter. The improved open cylindrical grip strength prototype should be able to hold a textured cylinder approximately one inch in diameter with significant mass for an extended period of time. Functionalities seen in the new product should remain largely the same if not improved when compared to the existing *Phoenix Reborn* model, minimizing substandard functionality sacrifices. Level of comfort should also be considered when developing the prototype to not have overexertion or harm to the user by straying too far from current standards. Simplicity and ease of use should also be considered so that users will not have to go through an overly intense learning curve prior to efficient and effective use.

Client requirements:

- Develop a prosthetic hand that is capable of an improved strength cylindrical grip
- Device must be able to pick up and hold a textured cylinder that will be supplied by the client
- Include a mechanism that limits overexertion of the user while using the prosthetic
- Ensure that the low-cost nature of the initial product is maintained with the prototype
- Possess equivalent or more accessible manufacturing intensity when compared to existing e-Nable models

enableGripStrength-Product-Design-Specifications.pdf(107.4 KB) - download

2021/10/1 Design Matrix

Matthew Wroblewski - Oct 19, 2021, 11:38 PM CDT

Title: Product Design Specifications

Date: 2021/10/01

Content by: Matthew Wroblewski

Present: The Team

Goals: Create and Upload the Design Matrix

Content:

Design Matrix Criteria

Designs Criteria (*weight)	Design One Phalange Extension		Design Two Thumb Relocation		Design Three Bar Thumb	
Grip Versatility (30)	5/5	30	4/5	24	3/5	18
Safety (15)	4/5	12	5/5	15	3/5	9
Cost (15)	4/5	12	3/5	9	3/5	9
Ease of Fabrication (15)	4/5	12	3/5	9	3/5	9
Product Weight (15)	4/5	12	5/5	15	4/5	12
Aesthetics (10)	4/5	8	3/5	6	3/5	6
Total (100)	**86**		**78**		**63**	

*Note: When referring to weight it is always *x/100*

Design Specifications

Phalange Extension: This design will feature an added phalange to the existing model, creating an extra degree of freedom for the finger as well as lengthening it.

Thumb Relocation: This design will relocate the thumb to a location that is in greater opposition to the phalanges. Testing will be done to find an optimal positioning, but current ideas include thumb reposition on the anterior side of the wrist, or in the same location as current with a different angle towards the palmar side of the hand. The thumb may also be lengthened during the design process.

Bar Thumb: This design would solely focus on a relocation of the thumb to the anterior side of the wrist and replace the thumb with a flat bar piece attached to a curved rod piece. Essentially, a piece that follows the path of the thumb and looks like an upside down brake pedal in a car will be used to grasp over the top of the fingers so that they will have an increased crushing strength and thus an improved grip strength when picking items up.

Design Criteria

Grip Versatility - The ability of the design to pick up multiple different types of objects to complete tasks of daily living.

Safety **-** The design must be able to operate with an equivalent safety rating of the existing models. While this is difficult to test directly in a cost effective manner for this project, the anticipated ability of the design to not experience a failure that would have the potential to harm the user will be used.

Cost **-** The total cost that would be anticipated to fabricate and test the design.

Ease of Fabrication - Takes into consideration the physical fabrication of the design for the team as well as the user. Also taken into consideration is the 3D modelling that would have to be completed to print the prototype by the team and any special instructions that would need to be accounted for when a user wants to print this design.

Weight - The design should remain as similar in weight to the current model as possible without compromising function and durability.

Aesthetics - The physical appearance of the design should account for most user’s wants of the prosthetic to feel like an extension of themselves and thus not deviate too far from the appearance of a sound hand.

Conclusions/action items:

We will submit this to our advisor and wait for feedback, but also move forward in the creation of our selected prototype.

2021/12/12 Final SolidWorks Models

Matthew Wroblewski - Dec 12, 2021, 1:29 PM CST

Title: Final SolidWorks Models

Date: 12/12/2021

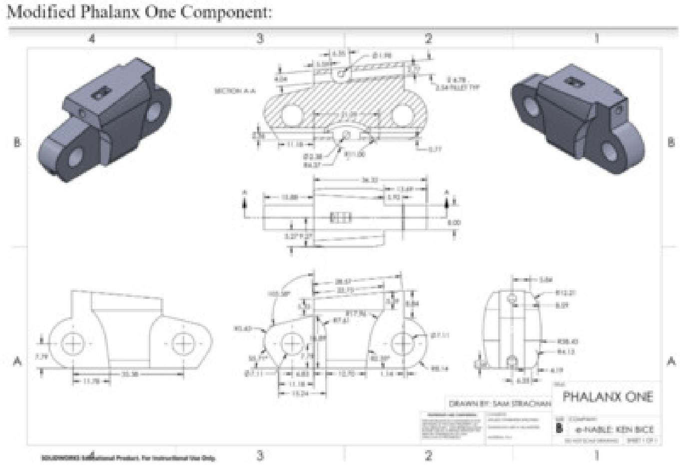
Content by: Matthew Wroblewski (Models/Drawings by Sam Strachan)

Present: n/a

Content:

Matthew Wroblewski - Dec 12, 2021, 1:28 PM CST

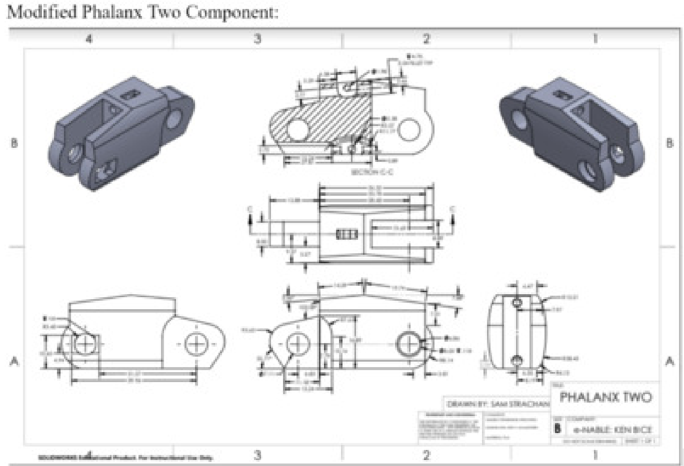
Modified Phalanx One Component:



modifiedOneDrawing.PNG(292 KB) - download

Matthew Wroblewski - Dec 12, 2021, 1:28 PM CST

Modified Phalanx Two Component:



modifiedTwoDrawing.PNG(303.3 KB) - download

2021/10/12 P1 Expenses and Materials

Matthew Wroblewski - Oct 19, 2021, 11:39 PM CDT

Title: Phase 1 Expenses and Materials

Date: 10/12/2021

Content by: Matthew Wroblewski

Goals: Log the phase 1 printing materials and expenses

Content:

Table 2. Cost breakdown of all components currently used for the prototype.

Component	Material	Unit Cost	Quantity	Total Cost
3D Printed Parts (Phalanx)	Polylactic Acid Filament (PLA)	$0.08 per gram	18 g/part, 4 parts = 72 g	$5.76
Elastic Retraction Cables	1 mm Elastic Jewelry Cord	$0.79 per meter	~ 0.92 m	$0.73
Nylon Thread Contraction Cables	1 mm Nylon Jewelry Thread	$0.69 per meter	~ 0.92 m	$0.63
Phoenix Reborn Hand	PLA, Bolts (3), Velcro, Foam	~ $40	1 Hand	$40
			Total Cost:	$47.12

Conclusions/action items:

Work on phase 1 testing so that phase 2 design can begin

2021/10/18 e-NABLE Kit Materials

Matthew Wroblewski - Oct 19, 2021, 11:40 PM CDT

Title: e-NABLE Kit materials

Date: 2021/10/18

Content by: Matthew Wroblewski

Present: The Team

Goals: Go over what the official materials recommended and sold by e-NABLE are beyond what our client has told us

Content:

https://shop3duniverse.com/collections/3d-printable-kits/products/phoenix-hand-by-e-nable-assembly-materials-kit#v32622587858

TENSIONER SCREWS	(4) Pan head Phillips sheet metal screws #4 x 3/4” (4) Pan head Phillips sheet metal screws #6 x 1” (4) Pan head Phillips sheet metal screws #8 x 1 ¼”
PALM SCREWS	(15) Countersink head Phillips wood screws #4 x 3/8” (15) Countersink head Phillips wood screws #6 x ½” (15) Countersink head Phillips wood screws #8 x 5/8”
CORDS ("TENDON" LINES)	(16 feet) 80 lbs strength braided fishing line (10 feet) Flexible cord 1.0mm (10 feet) Flexible cord 2.0mm

ELASTIC BANDS	(100) Non-latex extra heavy grade dental bands 1/4" size (100) Non-latex extra heavy grade dental bands 5/16" size
FIRM FOAM PADDING	(12" x 6”) 1/8” thick self-adhesive firm foam padding
GEL FINGERTIP GRIPS	(10) Size 3 Lee Tippi Gel Fingertip Grips
VELCRO STRAPS	(2) Velcro straps, 12” long, 1” wide with buckle

Conclusions/action items:

The team will need to take into consideration the accessible materials versus those the client provided us with as we move forward with the process.

2021/12/12 P2 Expenses and Materials

Matthew Wroblewski - Dec 12, 2021, 1:31 PM CST

Title: Phase 1 Expenses and Materials

Date: 10/12/2021

Content by: Matthew Wroblewski

Goals: Log the phase 2/final printing materials and expenses

Content:

Item	Description	Manufacturer	Date	QTY	Cost Each	Total	Link
Prototyping							
First Print	2 M/F new phalanx 20% infill	Makerspace	10/12	1	$1.44	$1.44	n/a
Second Print	Improved phalange (two phalanx components, one pin) Formlabs tough resin	Makerspace	11/1	1	$7.58	$7.58	n/a
Third Print	1 male-male phalanx 1 male-female phalanx 80% infill, intended PLA/PVA	Makerspace	11/5	1	$2.32	$2.32	n/a
Fabrication							
Fourth Print	4 male-male phalanx pieces (40% infill PLA with PVA Support) 4 male-female phalanx pieces (40% infill PLA with PVA Support)	MakerSpace	11/12	1	$7.76	$7.76	n/a

Fifth Print	Palm cover (PLA no support) 1 M/F phalanx reprint (PLA/PVA)	Makerspace	11/17	1	$3.22	$3.22	n/a
TOTAL:							**$22.32**

Zero-Expense components from client:

Component	Material	Unit Cost	Quantity	Total Cost
Elastic Retraction Cables	1 mm Elastic Jewelry Cord	$0.79 per meter	~ 0.92 m	$0.73
Nylon Thread Contraction Cables	1 mm Nylon Jewelry Thread	$0.69 per meter	~ 0.92 m	$0.63
Phoenix Reborn Hand	PLA, Bolts (3), Velcro, Foam	~ $40	1 Hand	$40
			Total Cost:	$41.36

2021/10/12 Phase 1 Printing

Matthew Wroblewski - Oct 17, 2021, 11:09 PM CDT

Title: Phase 1 Expenses and Materials

Date: 10/12/2021

Content by: Matthew Wroblewski

Goals: Log the phase 1 printing (pictures), the print has not been added to the existing hand as of yet.

Content:

- Post printing pickup from the Makerspace

- Post support removal/clean up

Conclusions/action items:

The team will work together to rebuild the hand using our new piece and observe if any changes need to be made before moving forward onto phase 2.

11/17 2021 Phase 2 Printing

Matthew Wroblewski - Dec 12, 2021, 1:58 PM CST

Title: Phase 2 Printing

Date: 11/1 through 11/17

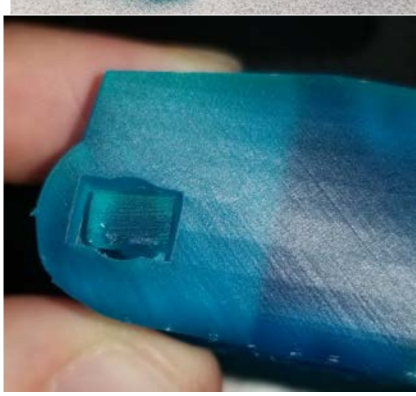
Content by: Matthew Wroblewski

Present: n/a

Goals: Log the team prints and thoughts as we progress through the fabrication process

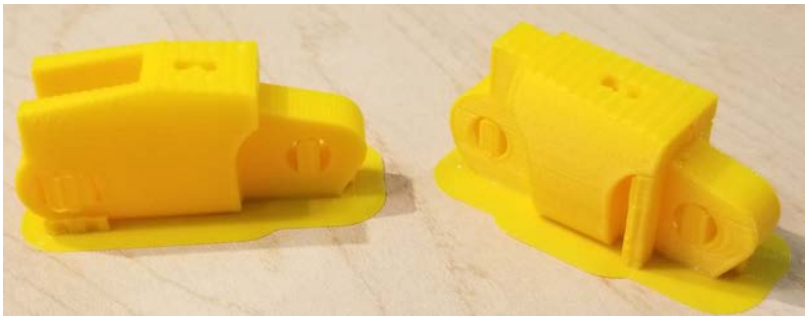
Content:

11/1/2021

- Second print of fabrication, the team used Formlabs Tough Resin to print two phalanx components that were modified in SolidWorks as well as one upscaled pin
- The total cost of the print was $7.58
- The results were mixed very positive and a little bit of failure
- The prints themselves were very high quality with easy to remove supports
- However, the cost of the prints were too much to be aligned with e-NABLE's mantra (and the fact that most people do not have a resin printer) and the pin piece was not upscaled properly
- 
-  

11/5/2021

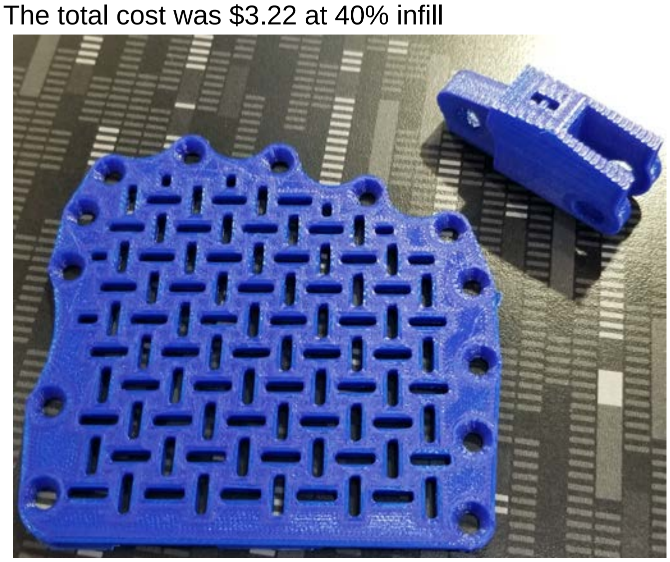
- For the next stage of printing, the model was slightly adjusted to feature a bigger internal diameter pin hole and attempted to be printed in PLA and PVA
- The PLA portion of the print went very well, but unfortunately the supports were also composed of PLA and not PVA

- The total cost of the print was $2.32 at 80% infill
- 

11/12/2021

- With the dimensions honed in and the use of PLA being confirmed feasible, the team printed eight phalanx pieces with PLA using water-soluble PVA supports
- the print overall was a success, but some pieces were a slightly distorted towards the rear, with one piece being unusable
- The total cost was $7.76 at 40% infill
- 
- (See the piece in the second row from the bottom on the left side with the distortion)

11/17/2021

- This should be the last set of printing by the team
- The hand base plate was printed using PLA, and a replacement phalanx piece was printed using PLA with PVA supports again
- The total cost was $3.22 at 40% infill
- 

Conclusions/action items:

Fabrication overall went well with some minor hiccups in the process, the team will now begin to assemble and test the hand

2021/12/10-Testing Protocol and Data Collection

KENZIE HURT - Dec 10, 2021, 9:46 AM CST

Title: Testing Protocol and Data Collection

Date: 12/10/2021

Content by: Kenzie Hurt

Present: N/A

Goals: To provide the protocol for both types of testing

Content:

Qualitative testing protocol:

1. Start with a fully assembled version of the phoenix reborn hand and the various testing objects (Red Bull can, Bubly can, Arizona Iced Tea can, Hydro Flask) on a level surface.
2. Begin with the objects at full volume. Use the testing rod on the prosthetic hand and attempt to lift the object completely off the level surface. This should be completed with every object. Record a yes if it successfully lifted the object off the surface with no support and no if it was not able to lift the object.
3. Complete this testing with each object filled to its full volume.
4. Now add rubber fingertip grip additions to the pinky, ring, middle and index fingers. Repeat testing with the full volume and empty volume for each of the objects and record results.
5. Now to test the new prototype, disassemble the hand and reassemble it with the phalanx addition.
6. Complete testing of the new prosthetic using the empty and filled weights for each of the 4 objects.
7. Repeat steps of adding “page turner” additions to the pinky, ring, middle and index fingers on the prototype.
8. Complete testing again using filled and empty volumes and record data.

Quantitative (Hand dynamometer) testing protocol:

1. Connect the hand dynamometer and open up the BIOPAC Student Lab Software
2. Calibrate the dynamometer and prepare the file for data collection
3. Hold the dynamometer vertically and position the prosthetic hand in a position such that the fingers will close directly onto the sensor, steadying the hand on the table top
4. Start the recording and wait two seconds
5. Close the hand as far it will go for two seconds
6. Relax the hand for two seconds
7. Repeat steps 5 and 6 for five more hand flexions (closures)
8. Stop the recording and end collection
9. Go to the data analysis section on the BIOPAC software and export the graph as an image
10. Repeat the testing for all prototypes to be tested and analyzed

Conclusions/action items:

The team was able to complete the qualitative testing the week before Thanksgiving on Friday, November 19 and the quantitative testing on Thursday, December 2. Data analysis and statistics were done the week following the quantitative testing. Data collection can be seen attached below.

KENZIE HURT - Dec 10, 2021, 9:47 AM CST

Test One - NO Finger Grips														
		Level One ("Empty")				Level Two ("Half full")				Level Three ("Full")				
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Original Hand	Trial 1:													
	Trial 2:													
	Trial 3:													
Modified Hand	Trial 1:													
	Trial 2:													
	Trial 3:													Total
Total # of Yes (Original Hand)														
Total # of Yes (Modified Hand)														
Weighted Score (Original Hand)														
Weighted Score (Modified Hand)														

Test Two - Finger Grips														
		Level One ("Empty")				Level Two ("Half full")				Level Three ("Full")				
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Original Hand	Trial 1:													
	Trial 2:													
	Trial 3:													
Modified Hand	Trial 1:													
	Trial 2:													
	Trial 3:													Total
Total # of Yes (Original Hand)														
Total # of Yes (Modified Hand)														
Weighted Score (Original Hand)														
Weighted Score (Modified Hand)														

Test One - Finger Grips Graphs									
	Weight					Size (Diameter)			
	Empty	Half Full	Full			Red Bull	Soda	Arizona Tea	Hydroflask
Original Hand					Original Hand				
Modified Hand					Modified Hand				

Testing_Data_Collection.xlsx(13.2 KB) - download

KENZIE HURT - Dec 10, 2021, 9:47 AM CST

Quantitative Qualitative Testing
Possible test objects:
- Red Bull can full vs. empty
- Soda can full vs. empty
- Arizona tea can full vs. empty
- Hydro Flask vs empty.

Might end up with in between data points as well, will play it by ear

4 different test sequences 2 for each hand with and without grips
Creating a weighting system for each task and then awarding points based on ability or inability to complete the task. Will end up in some sort of design matrix or visual chart configuration

Dynamometer (Purely Quantitative Testing)
Grab and release then do it 6 or more times

Task to be completed: Pick up object completely off the table with no assistance.

Red bull – 8.4 oz – 250 mL
- Empty weight = 10g
- Full weight = 281 g

Bubly – 16oz – 473 mL
- Empty weight = 17g
- Full weight = 486g

Arizone Tea – 23oz – 680 mL
- Empty weight = 29g
- Full weight = 713g

Object	Redbull 8.4oz	Bubly 16oz	Arizona Tea 23oz	Hydroflask 32oz
Empty weight	10g	17g	29g	434g
Full Weight	281 g	486 g	713g	1350g

Hydroflask
- Empty weight = 434g
- Full weight = 1350g

<u>Original Hand w/o Grips</u>
Red bull Full: **no**
Red bull empty: **yes**
Bubly Full: **no**
Bubly Empty: **yes**
Arizone Tea Full: **no**

Testing_Protocol_Data.pdf(49.8 KB) - download

2021/12/10-Testing Data and Analysis

KENZIE H

Title: Testing Data and Analysis

Date: 12/10/21

Content by: Kenzie Hurt

Present: N/A

Goals: To show the analysis of our data and prove that it has statistical significance difference.

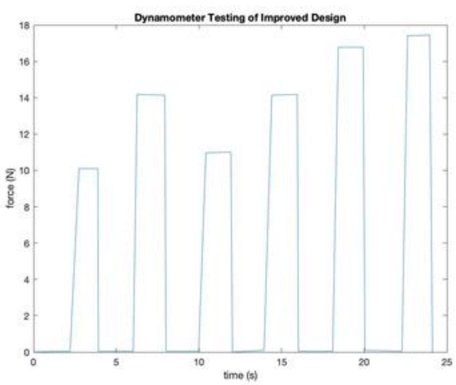
Content:

- After the data was collected in BIOPAC software as a graph, the graph was exported as an image as it could not give numerical data in any file form.
- I then used a digitizing software called Engauge Digitizer which uses pixel dimensions and user inputs to calculate accurate data points based on the graph uploaded. This digitized data was then exported as a .csv file wh
- After loading the data into MatLab, I ran a t-test to prove that the improved design of our hand had a significant difference when compared to the original hand.
- To prove significant difference, the p value must be less than 0.05 and our p value was 1.49e-09. This proves that our design is significantly different than the original design, therefore showing that our improved design d

Conclusions/action items:

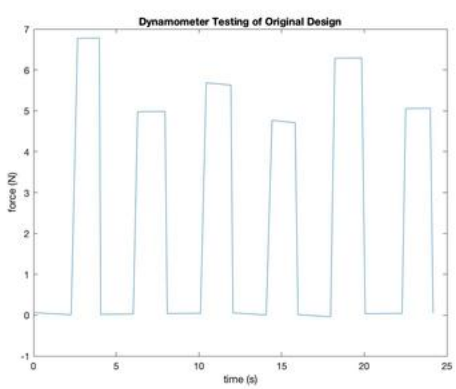
This concludes the data analysis of our quantitative testing with the dynamometer. After running the t-test, it was proven that our improved design did significantly improve the grip strength of the prosthetic as compared to the or
Matlab code.

KENZIE HURT - Dec 10, 2021, 9:18 AM CST



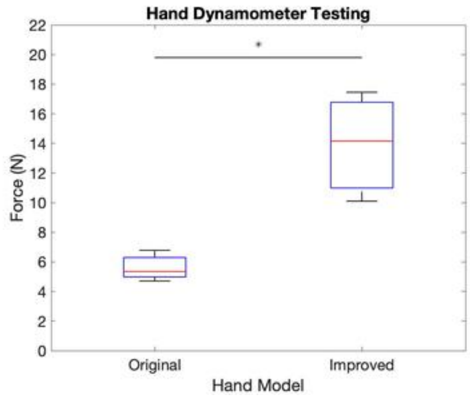
Improved.jpg(46 KB) - download

KENZIE HURT - Dec 10, 2021, 9:18 AM CST



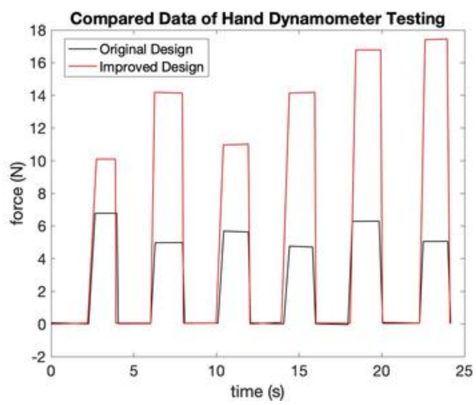
Original.jpg(44.7 KB) - download

KENZIE HURT - Dec 10, 2021, 9:18 AM CST



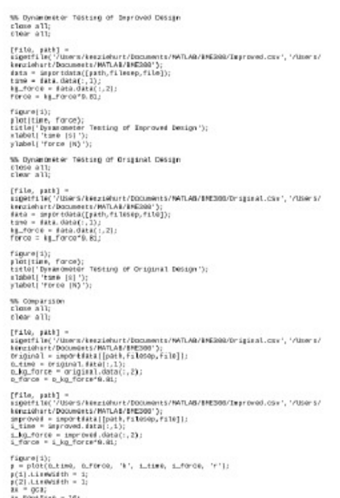
boxplot.jpg(43.2 KB) - download

KENZIE HURT - Dec 10, 2021, 9:18 AM CST



Compared.jpg(68.9 KB) - download

KENZIE HURT - Dec 10, 2021, 9:23 AM CST



```
%% Dynamometer Testing of Improved Design
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Improved.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
data = importdata([path,filesep,file]);
time = data.data(:,1);
kg_force = data.data(:,2);
force = kg_force*9.81;

figure(1);
plot(time, force);
title('Dynamometer Testing of Improved Design');
xlabel('time (s)');
ylabel('force (N)');

%% Dynamometer Testing of Original Design
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Original.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
data = importdata([path,filesep,file]);
time = data.data(:,1);
kg_force = data.data(:,2);
force = kg_force*9.81;

figure(1);
plot(time, force);
title('Dynamometer Testing of Original Design');
xlabel('time (s)');
ylabel('force (N)');

%% Comparison
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Original.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
original = importdata([path,filesep,file]);
o_time = original.data(:,1);
o_kg_force = original.data(:,2);
o_force = o_kg_force*9.81;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Improved.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
improved = importdata([path,filesep,file]);
i_time = improved.data(:,1);
i_kg_force = improved.data(:,2);
i_force = i_kg_force*9.81;

figure(1);
p = plot(o_time, o_force, 'k', i_time, i_force, 'r');
p(1).LineWidth = 1;
p(2).LineWidth = 1;
ax = gca;
ax.FontSize = 16;
title('Compared Data of Hand Dynamometer Testing');
```

dynamometer_testing.m(2.4 KB) - download

2021/12/10-Testing Visuals

KENZIE HURT - Dec 10, 2021, 9:51 AM CST

Title: Testing Visuals

Date: 12/10/2021

Content by: Kenzie Hurt

Present: N/A

Goals: To provide visuals (pictures and videos) of our testing.

Content:

- Pictures and video of testing and the model we used for testing.

Conclusions/action items:

Below are pictures and videos of our testing. There are also pictures of the model of hand we assembled to show how the string was tensioned.

KENZIE HURT - Dec 10, 2021, 10:00 AM CST

IMG_9156.mov(39.5 MB) - download This is a video of how the testing was completed with the hand dynamometer.

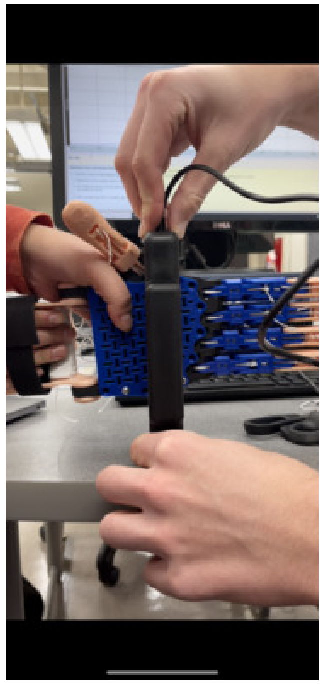
KENZIE HURT - Dec 10, 2021, 9:59 AM CST

IMG_9158.HEIC(3.3 MB) - download This is an image that shows the backside of the hand

KENZIE HURT - Dec 10, 2021, 9:59 AM CST

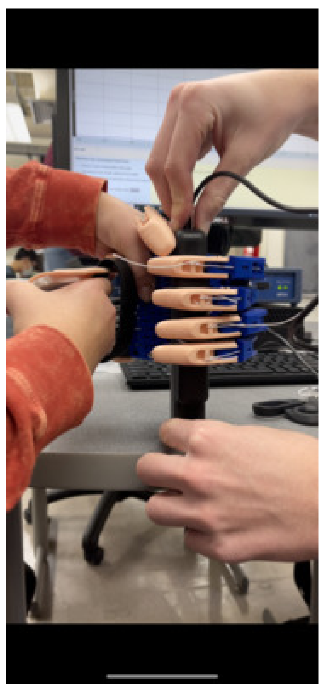
IMG_9159.HEIC(3.5 MB) - download This is an image that shows the palm side of the hand

KENZIE HURT - Dec 10, 2021, 9:58 AM CST



IMG_9181_2.PNG(11.5 MB) - download This image shows the hand dynamometer placement in relation to the prosthetic.

KENZIE HURT - Dec 10, 2021, 9:57 AM CST



IMG_9180_2.PNG(11.8 MB) - download This image shows the hand contracting onto the hand dynamometer during testing.

KENZIE HURT - Dec 11, 2021, 6:47 PM CST

IMG_9185.HEIC(1.4 MB) - download Hand successfully picking up the Hydroflask.

KENZIE HURT - Dec 11, 2021, 6:47 PM CST

IMG_9187.HEIC(1.1 MB) - download This image is analogous with the next image showing the initial position of the hand grasping the test object.

KENZIE HURT - Dec 11, 2021, 6:48 PM CST

IMG_9189.HEIC(1.3 MB) - download This image shows the final position of the hand successfully picking up the test object.

Current Prosthetic in Motion

KENZIE HURT - Oct 01, 2021, 4:52 PM CDT

IMG_8660.MOV(26.2 MB) - download

12/12/2021 Final SolidWorks Files

Matthew Wroblewski - Dec 12, 2021, 1:36 PM CST

Title: Final SolidWorks Files

Date: 12/12/2021

Content by: Matthew Wroblewski (Files by Sam Strachan)

Present: N/A

Goals: Log the teams final models for the project

Content:

Conclusions/action items:

Send the files over to our client and wait for feedback from the e-NABLE community

Matthew Wroblewski - Dec 12, 2021, 1:37 PM CST

Original_Phalange_3.0.STL(158.7 KB) - download

Matthew Wroblewski - Dec 12, 2021, 1:37 PM CST

Phalange_Extension_3.0.STL(152.4 KB) - download

Matthew Wroblewski - Dec 12, 2021, 1:37 PM CST

Phoenix_reborn_palm_mesh_thick_left.stl(305.1 KB) - download

9/14/2021 Anatomy-Based Prosthetic

Matthew Wroblewski - Sep 15, 2021, 10:15 AM CDT

Title: Human Hand Anatomy-Based Prosthetic Hand

Date: 9/14/2021

Content by: Matthew Wroblewski

Present: N/A

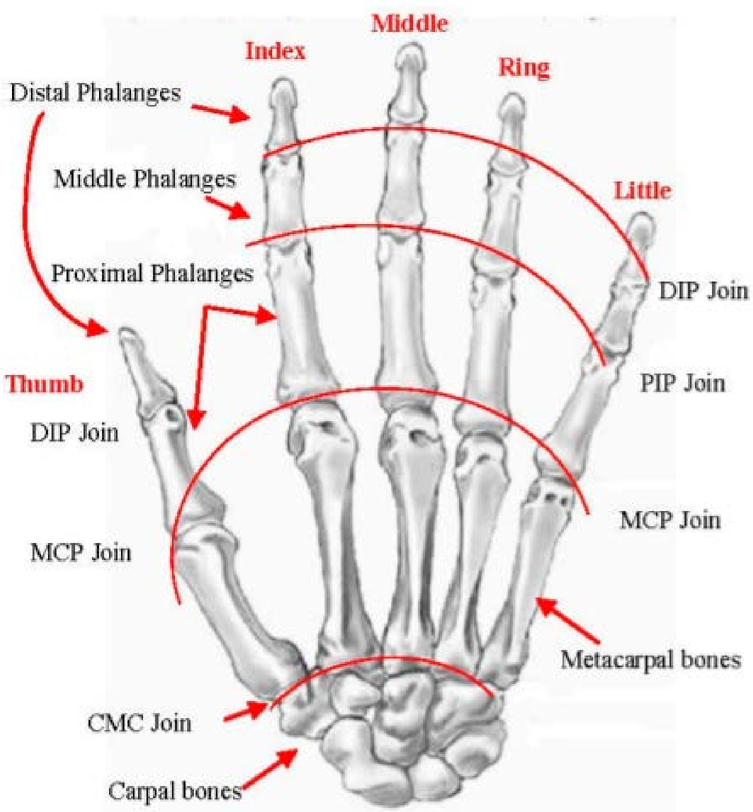
Goals: Learn more about the process of converting human anatomy into viable prosthetics.

Citation: Dunai L, Novak M, García Espert C. Human Hand Anatomy-Based Prosthetic Hand. Sensors (Basel). 2020;21(1):137. Published 2020 Dec 28. doi:10.3390/s21010137

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7795667/

Content:

- More than 3 million people experience hand amputations or loss for varying health reasons.
- Most common prosthetic hands are passive and are more visual rather than functional.
- Since most prosthetic hands are controlled by a single input individual joint or finger control is not allowed
- In the case of signal based prosthetics, in order to have more than 2 inputs more conditions are required such as triggering or force sensitive resistors
- 3D scans of hands were taken and then modelled using Inventor. PLA was used for all the pieces.



-
    - Hand Anatomy
    - 14 joints for the entire hand, Carpal and Metacarpal bones have 0 DOF

- The thumb is the only joint with sagittal plane movement
- The rest of the joints have 1 DOF with abduction & adduction in the frontal plane.

- Artificial ligaments are chosen from rubber materials with different hardness and elasticity characteristics.
- Individual finger control requires multiple joint actuation as well as joint specific contractions.

Conclusions/action items:

- Now that I have learned some more about how human anatomy effects the construction of hand prostheses I can begin to look into the everyday use of prosthetics.

Matthew Wroblewski - Sep 14, 2021, 10:00 PM CDT

sensors

Human Hand Anatomy-Based Prosthetic Hand

1. Introduction

anatomyHandProstheticArticle.pdf(4.3 MB) - download

9/14/2021 Passive Prostheses

Matthew Wroblewski - Sep 15, 2021, 10:30 AM CDT

Title: Passive Prosthetic Hands and Tools

Date: 9/14/2021

Content by: Matthew Wroblewski

Present: N/A

Goals: Improve knowledge of prosthetic classifications and the usages that may not have been thought of otherwise in order to take these ideas into consideration for the product.

Citation: Maat, B., Smit, G., Plettenburg, D., & Breedveld, P. (2018). Passive prosthetic hands and tools: A literature review. Prosthetics and orthotics international, 42(1), 66–74. https://doi-org.ezproxy.library.wisc.edu/10.1177/0309364617691622

Link: https://www-ncbi-nlm-nih-gov.ezproxy.library.wisc.edu/pmc/articles/PMC5810914/

Content:

- Passive protheses are defined as either static or adjustable prosthetic hands or tools.
- The force to control a grasping mechanism either electronically or body-powered makes a prosthetic considered active rather than passive.
- About 1/3 potential prosthetic hand uses uses a passive prosthesis
- Active prosthesis are often seen as a better solution than passive but can be difficult to control especially for young children, so passive prosthetics are recommended first as an adjustment period.
- A lot of users of passive prosthesis are older or have had a very extended time since amputation
  - active to passive over time
  - Appearance and comfort are at the forefront of passive prosthetic hands (ranked by users)
- Pull actions found particularly difficult with the passive hand and is a place where the active hand offers superior assistance

Conclusions/action items:

- This article was primarily focused on the use of passive rather than active prosthetics. As stated in the article most people (including myself) underestimate the amount of use that patients actually get out of a passive prosthetic and their ability to complete everyday activities, so as a group we must make sure that we are not limiting the accomplishable task and should look at the intended group as exceptionally capable.
- More research can be done into everyday use of active prosthetics.

Matthew Wroblewski - Sep 14, 2021, 10:46 PM CDT

Special Issue Article

Passive prosthetic hands and tools: A literature review

Bartjan Maat, Gerwin Smit, Dick Plettenburg and Paul Breedveld

Abstract

Background: The group of passive prostheses consists of prosthetic hands and prosthetic tools. These can either be static or adjustable. Limited research and development on passive prostheses has been performed although many people use these prosthesis types. Although some publications describe passive prostheses, no recent review of the peer-reviewed literature on passive prostheses is available.

Objective: Review the peer-reviewed literature on passive prostheses for replacement of the hand.

Study design: Literature review.

Methods: Four electronic databases were searched using a Boolean combination of relevant keywords. English-language articles relevant to the objective were selected.

Results: In all, 28 papers were included in the review. Publications on passive prosthetic hands describe their users, usage, functionality, and problems in activities of daily living. Publications on prosthetic tools mostly focus on sport, recreation, and vehicle driving.

Conclusion: Passive hand prostheses receive little attention in prosthetic research and literature. Yet one out of three people with a limb deficiency uses this type of prosthesis. Literature indicates that passive prostheses can be improved on pulling and grasping functions. In the literature, ambiguous names are used for different types of passive prostheses. This causes confusion. We present a new and clear classification of passive prostheses.

Clinical relevance

This review provides information on the users of passive prosthetic hands and tools, their usage and the functionality. Passive prostheses receive very little attention and low appreciation in literature. Passive prosthetic hands and tools show to be useful to many unilateral amputees and should receive more attention and higher acceptance.

Keywords

Upper limb, prosthesis, passive, cosmetic, hand, tool, adaptation, static, adjustable

Background

Classification of passive prostheses

The wide range of prostheses for replacement of the hand can be divided into active and passive prostheses. The force to control the grasping mechanism of active prostheses is applied to this mechanism internally, for example, by an electric actuator or a body-powered cable. In passive prosthesis, the force to adjust the grasping mechanism is applied externally, for example, by the sound hand.

There are various types of passive prostheses. In the current literature, different terms are used for the same type of device, and often the same name is used for different types of passive devices. As a result, it is often unclear which type of device is discussed. To avoid any

Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, Delft, The Netherlands

Corresponding author:
Gerwin Smit, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, 2628 CD Delft, The Netherlands.

passiveProstheticHandLiteratureReview.pdf(407.4 KB) - download

9/14/2021 Mutli-Grip Pattern

Matthew Wroblewski - Sep 24, 2021, 12:13 PM CDT

Title: Design of Multi-Grip Patterns Prosthetic Hand With Single Actuator

Date: 9/14/2021

Content by: Matthew Wroblewski

Present: N/A

Goals: View a preexisting design of a grip modifying actuator in a prosthetic to learn more about the mechanics behind it as well as note if there are any ideas that could be considered for our product.

Citation: P. Wattanasiri, P. Tangpornprasert and C. Virulsri, "Design of Multi-Grip Patterns Prosthetic Hand With Single Actuator," in IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 26, no. 6, pp. 1188-1198, June 2018, doi: 10.1109/TNSRE.2018.2829152.

Link: https://ieeexplore-ieee-org.ezproxy.library.wisc.edu/stamp/stamp.jsp?tp=&arnumber=8345188

Content:

- Body powered prosthetics operate by movement through wires or cables and have one degree of freedom with only a single grip pattern.
  - typically sacrifice cosmetic appearance to achieve functionality
- ADL = Activity of Daily Living
- Grip force of body powered prosthetics is typically enough for ADLs but requires force from user for continuous operation.
  - Some designs can swap between open and closed
- There is research being done into body powered hydraulics to improve grip strength to exertion ratio
- Some designs have 5 individual actuators coupled with each digit for individual finger use
- Some designs use 2 actuators to separate finger use and thumb use
- **Look into: Continuum differential mechanism (22), spring-like mechanism (23,24,25), compliant structure (26)**
- Actuators tend to improve the number of grip patterns, but also can sacrifice strength by decreasing the amount of usable space
- Precision grip, power grip, and lateral grip are used at ~ 35, 35, and 20% respectively in ADL
  - Precision = finger tips to thumb
  - Power = finger tips to palm
  - Lateral = thumb to side of index
- Finger flexion speed is important for proper everyday use. 170 to 200 degree/second, b ut commercial hands value typically between 60-103.
- Weight, size, and hand anatomy are also important for proper usage.
  - Average hand weight is 400g, prosthetics vary between 450g and 2200g
    - Prosthetic socket applies force onto muscle rather than bone so are perceived as heavier by users.
- This design proposes an actuator similar to the concept that I thought might be possible during our first team meeting where an actuator works to have two conformations which individually allow for an alteration in grip force. This design works to alternate between precision grip and power grip
- The article then goes into detail about the mechanics of this design which may be useful at a later date

- For everyday pick-and-place tasks, finger flexion speed has been found to be between 170 to 200 degree/second [1]

Conclusions/action items:

- Continue to learn about other currently existing hand prosthetics that are available to gain knowledge for possible alterations to the e-Nable hand.

Matthew Wroblewski - Sep 14, 2021, 10:59 PM CDT

Design of Multi-Grip Patterns Prosthetic Hand With Single Actuator

Design_of_Multi-Grip_Patterns_Prosthetic_Hand_With_Single_Actuator.pdf(4.3 MB) - download

9/14/2021 DEKA Hand

Matthew Wroblewski - Sep 15, 2021, 12:15 PM CDT

Title: The DEKA hand: A multifunction prosthetic terminal device—patterns of grip usage at home

Date: 9/14/2021

Content by: Matthew Wroblewski

Present: N/A

Goals: Try and learn more about what the most used/valuable grip type is/would be to focus on improving for our project

Citation: Resnik, L., Acluche, F., & Borgia, M. (2018). The DEKA hand: A multifunction prosthetic terminal device-patterns of grip usage at home. Prosthetics and orthotics international, 42(4), 446–454. https://doi-org.ezproxy.library.wisc.edu/10.1177/0309364617728117

Link: https://journals-sagepub-com.ezproxy.library.wisc.edu/doi/epub/10.1177/0309364617728117

Content:

- Human hand can make over 30 grasp patterns, while most prosthetics allow 1
- DEKA has 6 powered hand grips
- This research group completed trials investigating the use of each grip type

Table 2. Interval length, power on time, and proportion of time spent in each grip pattern.

	First 4 weeks (*N* = 15)	Later months (*N* = 17)	Testing Use 1 (*N* = 13)	Testing Use 2 (*N* = 7)
	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)
Interval length (days)	28 (20, 30)	44 (28, 54)	NA	NA
Power on time (h)	37.3 (9.5, 79.4)	46.8 (13.0, 93.8)	2.1 (1.8, 2.4)	2.3 (1.7, 3.2)
Use hours/day	1.2 (0.5, 3.6)	1.1 (0.3, 2.1)	1.8 (1.0, 2.0)	1.7 (0.3, 2.6)
Grip				
Power	0.56 (0.42, 0.88)	0.53 (0.40, 0.80)	0.22 (0.17, 0.30)	0.38 (0.22, 0.44)
Tool	0.03 (0.01, 0.04)	0.01 (0.01, 0.04)	0.01 (0.00, 0.03)	0.01 (0.01, 0.03)
Pinch open	0.01 (0.00, 0.06)	0.01 (0.01, 0.03)	0.06 (0.03, 0.18)	0.06 (0.04, 0.11)
Pinch closed	0.04 (0.02, 0.20)	0.04 (0.02, 0.05)	0.10 (0.07, 0.17)	0.21 (0.06, 0.30)
Lateral	0.12 (0.05, 0.19)	0.06 (0.04, 0.31)	0.25 (0.16, 0.33)	0.20 (0.12, 0.31)
Chuck	0.04 (0.01, 0.12)	0.04 (0.01, 0.11)	0.25 (0.06, 0.38)	0.15 (0.05, 0.20)

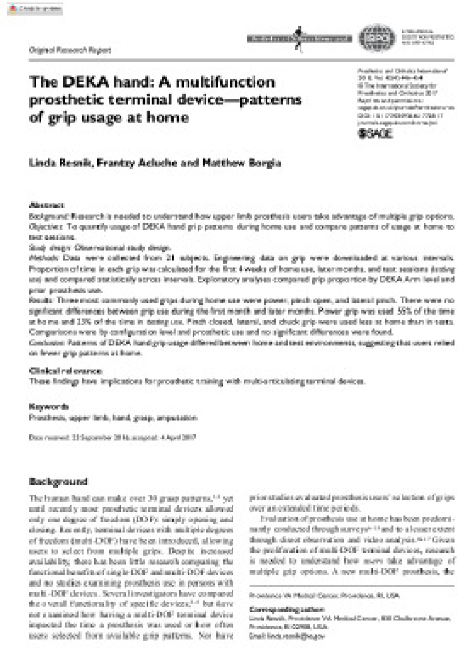
IQR: interquartile range.
NA: not applicable, given that post-test data were not necessarily downloaded on the day of test sessions.

-
    - Power grip was used in the great majority during at home use with lateral being the second most frequently used at first by greater but falling off to equate closed to pinch closed and chuck as experience with the prosthetic increased.
    - Power and lateral grip were used 75% of the time during at home use suggesting potential areas of focus in our project.

Conclusions/action items:

- Learned useful knowledge about what grip types are most useful in everyday life but this prosthetic is highly advanced by comparison and research into less advanced prosthetics that are 3D printed would prove useful

Matthew Wroblewski - Sep 14, 2021, 10:58 PM CDT



Original Research Report

The DEKA hand: A multifunction prosthetic terminal device—patterns of grip usage at home

Linda Resnik, Frantzy Acluche and Matthew Borgia

Abstract

Background: Research is needed to understand how upper limb prosthesis users take advantage of multiple grip options.
Objectives: To quantify usage of DEKA hand grip patterns during home use and compare patterns of usage at home to test sessions.
Study design: Observational study design.
Methods: Data were collected from 21 subjects. Engineering data on grip were downloaded at various intervals. Proportion of time in each grip was calculated for the first 4 weeks of home use, later months, and test sessions (testing use) and compared statistically across intervals. Exploratory analyses compared grip proportion by DEKA Arm level and prior prosthesis use.
Results: Three most commonly used grips during home use were power, pinch open, and lateral pinch. There were no significant differences between grip use during the first month and later months. Power grip was used 55% of the time at home and 13% of the time in testing use. Pinch closed, lateral, and chuck grip were used less at home than in tests. Comparisons were by configuration level and prosthetic use and no significant differences were found.
Conclusion: Patterns of DEKA hand grip usage differed between home and test environments, suggesting that users relied on fewer grip patterns at home.

Clinical relevance

These findings have implications for prosthetic training with multiarticulating terminal devices.

Keywords

Prosthesis, upper limb, hand, grasp, amputation

Date received: 23 September 2016; accepted: 4 April 2017

Background

The human hand can make over 30 grasp patterns,[1,2] yet until recently most prosthetic terminal devices allowed only one degree of freedom (DOF): simply opening and closing. Recently, terminal devices with multiple degrees of freedom (multi-DOF) have been introduced, allowing users to select from multiple grips. Despite increased availability, there has been little research comparing the functional benefits of single-DOF and multi-DOF devices and no studies examining prosthesis use in persons with multi-DOF devices. Several investigators have compared the overall functionality of specific devices,[3-5] but have not examined how having a multi-DOF terminal device impacted the time a prosthesis was used or how often users selected from available grip patterns. Nor have prior studies evaluated prosthesis users' selection of grips over an extended time periods.

Evaluation of prosthesis use at home has been predominantly conducted through surveys[6-13] and to a lesser extent through direct observation and video analysis.[14-17] Given the proliferation of multi-DOF terminal devices, research is needed to understand how users take advantage of multiple grip options. A new multi-DOF prosthesis, the

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Email: linda.resnik@va.gov

DEKAhand.pdf(572 KB) - download

9/14/2021 Cyborg Beast

Matthew Wroblewski - Sep 15, 2021, 12:25 PM CDT

Title: Cyborg beast: a low-cost 3d-printed prosthetic hand for children with upper-limb differences

Date: 9/14/2021

Content by: Matthew Wroblewski

Present: N/A

Goals: View a 3D printed prosthetic hand that is very similar to the e-Nable designs to see if there are any nuances that can be picked up on

Citation: Zuniga, J., Katsavelis, D., Peck, J., Stollberg, J., Petrykowski, M., Carson, A., & Fernandez, C. (2015). Cyborg beast: a low-cost 3d-printed prosthetic hand for children with upper-limb differences. BMC research notes, 8, 10. https://doi.org/10.1186/s13104-015-0971-9

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4304188/

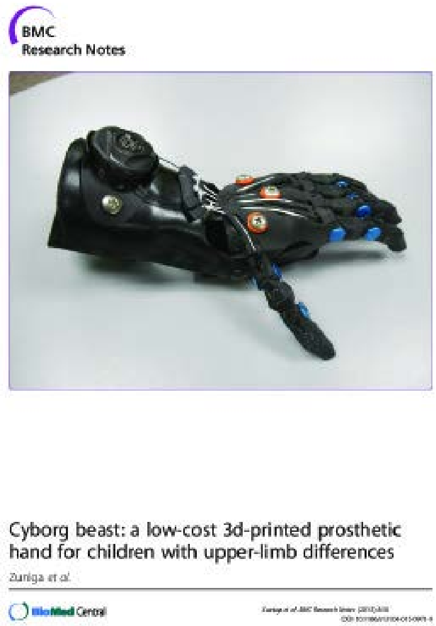
Content:

- 3D printed prosthetic very similar to that we will be working with:
- Prosthetic is activated by a non elastic cord and 20-30 degrees of wrist flexion resulting in a composite fist
- PLA was used as well as ABS (acrylonitrile butadiene styrene)
    - 1 mm lift nylon cord
    - 1.5 mm elastic cord
    - Velcro
    - medical grade firm padded foam
    - protective skin sock
    - dial tensioner system
- cost of materials ~$50
- 2.5 hours average full assembly time
- Weight at 140% original size is 184.2 grams
- Anthropometry was used for hand measurements, wrist flexion was used for range of motion
- Hand scale and wrist flexion charts were created that may be useful in the future but for now will likely not be a large factor in our project as we do not have an individual client to focus towards.

Conclusions/action items:

- Talk with the client to narrow down our goals and then continue research into materials, anatomy, math, and testing of hand prosthetics.

Matthew Wroblewski - Sep 14, 2021, 11:05 PM CDT


BMC
Research Notes

Cyborg beast: a low-cost 3d-printed prosthetic hand for children with upper-limb differences

Zuniga et al.

BioMed Central

cyborgBeast.pdf(1.7 MB) - download

9/23/2021 Soft 3D

Matthew Wroblewski - Sep 23, 2021, 6:46 PM CDT

Title: A Soft 3D-Printed Robotic Hand Actuated by Coiled SMA

Date: 9/23/2021

Content by: Matthew Wroblewski

Present: N/A

Goals: Review a paper about a hand that uses flexible 3D printing fibers rather than constructed joints and observe the results of the project

Citation: Deng E, Tadesse Y. A Soft 3D-Printed Robotic Hand Actuated by Coiled SMA. Actuators. 2021; 10(1):6. https://doi.org/10.3390/act10010006

Link: https://www.mdpi.com/2076-0825/10/1/6

Content:

- Flexible components are made out of thermoplastic polyurethane (TPU)
- *Table of existing actuation techniques below*
    - *Some other techniques used "twisted coiled polymer"*
- The design created in this article uses coiled shape memory alloy (SMAs) actuators which is something that is of little relevance to us on this project but an interesting part of their design is that they put these coils on a platform that extends up the forearm of the user. So, even if we could in theory minimize prosthetic size to an equivalent amount of the existing products, we could also consider creating a forearm extension to aid in the increase of grip strength during redesign, which would also possess cantilever force benefits during prolonged use as well.

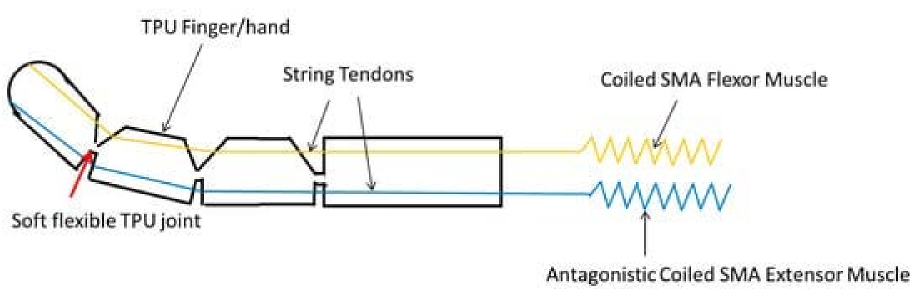


Figure 2. Schematic diagram of the robotic hand actuated by coiled SMA

- In Figure 2, note that while this product is again focused on a robotic hand and far more advanced than the necessities of this project, antagonistic fibers are used for muscle extension which is not something currently seen in e-Nable models and is another piece of information to be considered for our project
- Flexible fibers also allow for 3 DOF on each finger, which is not current on e-Nable hands as well
    - Thus, we could consider using flexible printing filament or look into "milling" out plastic and creating a joint
    - We would have to consider the strength of the joint however, and its longevity once the mass of the hand is intentionally compromised
        - Finite Element Analysis in SolidWorks
        - Multiple simulations for different force vectors

- Also worth mentioning is that the string is external of the hand and therefore too exposed for everyday use by our clients requirements
  - design alterations to account for this seem possible at first thought

- Table 1 - comprehensive summary of existing robotic and prosthetic hands using different modes of actuation

Type of Actuator	Motion Transmission Mode	No. of Actuators	Finger Return Mode	No. of Fingers	Weight	Total DOF	Name/ Developer
Muscles	Tendon	40	Muscles	5	0.4 kg (hand) +1.13 kg (forearm)	23	Human hand § (male) [38]
Electrical motors	Flexible driven train (flex shaft)	14	Actuator	5	--	14	Robonaut hand [19]
	Tendon driven mechanism	19	Torsional springs	5	0.09 kg (hand) +0.96 kg (forearm)	19	DART hand [14]
	Tendon/gear driven mechanism	16	Actuator	5	0.665 kg (hand) +3.3 kg (actuators)	16	NAIST hand 2 [12]
	Tendon driven mechanism	16	Helical springs	5	--	16	UB Hand 3 [18]
	Linkage mechanism	5	Actuator	5	0.42 kg (hand)	5	HIT-DLR hand [39]
	Tendon driven mechanism	10	Actuator	5	0.942 kg (hand + forearm)	16	Xu and Todorov [40]
	Tendon driven mechanism	2	Actuator	5	--	19	Pisa/IIT SoftHand 2 [41]
	Twisted string mechanism	3	Actuator	5	0.280 kg (hand)	10	UC Softhand [42]
	--	--	--	5	1.27 kg (hand)	6	DEKA LUKE Arm [15]
Fluidic actuators	Hinge structure	18	Elastomeric spring	5	--	13	Karlsruhe Univ., Germany [3]
Pneumatic	Tendon driven mechanism	38	Actuator	4	--	19	UTAH/MIT [22]

Type of Actuator	Motion Transmission Mode	No. of Actuators	Finger Return Mode	No. of Fingers	Weight	Total DOF	Name/ Developer
Nylon actuators	Tendon driven mechanism	10	Actuator/torsional springs	5	0.053 kg (hand) + 0.087 kg (forearm)	16	TCP UTD hand [7]
SMA	SMA wires	9	Actuator	3	--	8	SMA hand [26]
	SMA plates	2	Actuator	1	0.044 kg (finger)	1	Engeberg et al. [33]
	SMA plates	10	Actuator	5	0.282 kg (hand)	--	She et al. [34]
	Coiled SMA	22	Actuator	4	0.6 kg (hand)	11	Farias et al. [44]
	Coiled SMA	8	Actuator	5	0.235 kg (hand + forearm)	14	THIS PAPER (TPU SMA Hand) *

§ Natural hand for benchmark comparison. * The robotic hand developed in this study at the University of Texas at Dallas (UTD).

Conclusions/action items:

- Look back at all designs already reviewed and begin brainstorming or if necessary review more articles on less advanced designs.

Matthew Wroblewski - Sep 23, 2021, 1:36 PM CDT


actuators

Article

A Soft 3D-Printed Robotic Hand Actuated by Coiled SMA

Eric Deng and Yonas Tadesse

actuators-10-00006-v3.pdf(6.9 MB) - download

9/23/2021 Two Finger Concepts

Matthew Wroblewski - Sep 23, 2021, 7:31 PM CDT

Title: Design and evaluation of two different finger concepts for body-powered prosthetic hand

Date: 9/23/2021

Content by: Matthew Wroblewski

Present: N/A

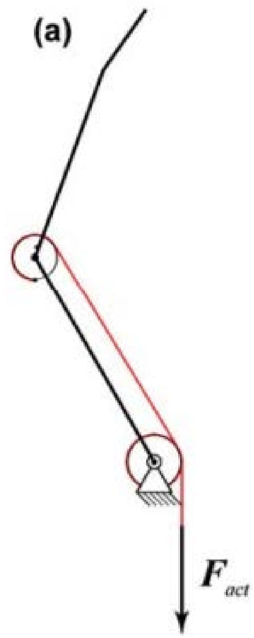
Goals: Review an article with a lot of calculations to discover information that we may need to include in calculations of our own

Citation: Smit, G., Plettenburg, D. H., & T. van der Helm, F. C. (2013). Design and evaluation of two different finger concepts for body-powered prosthetic hand. Journal of Rehabilitation Research & Development, 50(9), 1253–1265. https://doi-org.ezproxy.library.wisc.edu/10.1682/JRRD.2012.12.0223

Link: https://doi-org.ezproxy.library.wisc.edu/10.1682/JRRD.2012.12.0223

Content:

- Calculations on pinch force we conducted and in order to have rigid joints exceptional torque must be applied just to reach a target pinch force. (i.e. a 30N pinch force requires a torque of 2010 Nmm at the metacarpophalangeal joint (first knuckle) and 1110 Nmm in the proximal interphalangeal joint (second knuckle)
- It has to be taken into account that if springs are used, energy is conserved but only once the hand opens back up thus you have to account for energy loss in the system. Friction at joint rotations needs to also be taken into account
- Of the two designs they are looking at in this article, the pully system is more applicable, some advantages that they list for a design like this are
  - very lightweight, no strict dimension tolerances
  - Possible disadvantages - cable wear and tear, cable elasticity, cable runoff
  - Cable diagram seen here

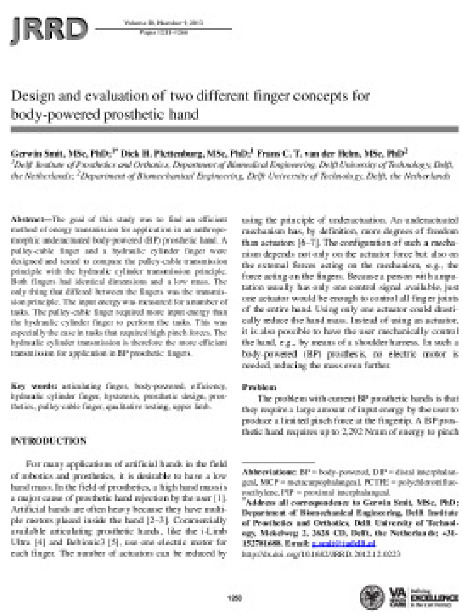


- Could a compound pulley system be used to create more knuckle freedom in our product redesign? --> brainstorm 9/23/2021

Conclusions/action items:

- Look into multiple DOF systems in prosthetic fingers/knuckles.
- Continue brainstorming
- Not as much mathematics that are directly applicable to the project as anticipated, future research will likely need to be conducted.

Matthew Wroblewski - Sep 23, 2021, 1:43 PM CDT



JRRD

Design and evaluation of two different finger concepts for body-powered prosthetic hand

Gerwin Smit, MSc, PhD; Dick H. Plettenburg, MSc, PhD; Frans C. T. van der Helm, MSc, PhD

Delft Institute of Prosthetics and Orthotics, Department of Biomedical Engineering, Delft University of Technology, Delft, the Netherlands; Department of Biomechanical Engineering, Delft University of Technology, Delft, the Netherlands

twoDifferentFingerConcepts.pdf(2.2 MB) - download

10/17/2021 3D Printer Research

Matthew Wroblewski - Oct 18, 2021, 5:45 PM CDT

Title: 3D Printer Research

Date: 10/17/2021

Content by: Matthew Wroblewski

Present: n/a

Goals: Reinforce my pre-existing knowledge on 3D printers, specifically those available at the Makerspace, so that alternate options can be explored besides the PLA on the Ultimaker and investigate advice received from a conversation with a Makerspace employee about the SLS Printers.

Link(s):

[1] https://making.engr.wisc.edu/3d-printers-2/

[2] https://formlabs.com/blog/ultimate-guide-to-stereolithography-sla-3d-printing/

[3] https://formlabs.com/blog/what-is-selective-laser-sintering/

[4] https://formlabs-media.formlabs.com/datasheets/1801089-TDS-ENUS-0P.pdf

[5] See Attached SDS for Ultimaker PLA

[6] https://www.hubs.com/knowledge-base/supports-3d-printing-technology-overview/

Content:

From Makerspace Website [1], these are the printers currently available for the team to use:

- Ultimaker (FFF)
    - Fused Filament Fabrication, what most people think about when they think of 3D Printing
    - Has many support structures and as a result orientation is very important when printing and can be very tedious on small, complex parts (as I observed trying to clean up our initial prototype print)
- Formlabs Form 2 (and 3) (SLA)
    - Stereolithography printing [2], also known as resin 3D printing, involves the use of a resin and a light source to cure the resin into a hardened plastic.
    - Builds "Upside down"
    - Has "thin ribs" of support structures [6]
- Formlabs Fuse 1 (SLS)
    - Selective Laser Sintering [3], uses a laser to "sinter" small particles of polymer powder into a solid structure
    - Standard Formlabs resin has sufficient material characteristics similar to that of PLA [4]
    - For SLS there's no need for support structures since the powder acts as support when the object is built up layer by layer. [6]
        - This is the information I was looking for, this feature alone will make the production of our prototypes much less time consuming, allowing for quicker printing and alterations as we move along in the process.

    - More expensive than PLA however, so we may hold off on using this printer until the later stages of the project.
- Stratasys F370 (FFF)
- Markforged & Dolomite Printers (FFF)
    - Dolomite - Designed for Microfluidics
    - Markforged - Prints in carbon fiber reinforced nylon

Conclusions/action items:

Bring this information to the team when we proceed with phase 2 printing.

Matthew Wroblewski - Oct 17, 2021, 10:10 PM CDT

Technical data sheet PLA

Ultimaker

Chemical composition	See PLA safety data sheet, section 3
Description	Ultimaker PLA filament provides a no-hassle 3D printing experience thanks to its reliability and good surface quality. Our PLA is made from organic and renewable sources. It's safe, easy to print with, and it serves a wide range of applications for both novice and advanced users
Key features	Good tensile strength and surface quality, easy to work with at high print speeds, user-friendly for both home and office environments, PLA allows the creation of high-resolution parts. There is a wide range of color options available
Applications	Household tools, toys, educational projects, show objects, prototyping, architectural models, as well as lost casting methods to create metal parts
Non-suitable for	Food contact and in vivo applications. Long term outdoor usage or applications where the printed part is exposed to temperatures higher than 50 °C

Filament specifications

	Value	Method
Diameter	2.85 ± 0.10 mm	-
Max roundness deviation	0.10 mm	-
Net Filament weight	350 g / 750 g	-
Filament length	~ 44 m / ~ 95 m	-

Color information

Color	Color code
PLA Green	RAL 6018
PLA Black	RAL 9005
PLA Silver Metallic	RAL 9006
PLA White	RAL 9010
PLA Transparent	N/A
PLA Orange	RAL 2008
PLA Blue	RAL 5002
PLA Magenta	RAL 4010
PLA Red	RAL 3020
PLA Yellow	RAL 1003
PLA Pearl White	RAL 1013

UM180821_TDS_PLA_RB_V11_2_.pdf(70.7 KB) - download

9/22/2021 Push Slide

Matthew Wroblewski - Sep 23, 2021, 12:39 PM CDT

Title: Individual Brainstorming Session

Date: 9/23

Content by: Matthew Wroblewski

Present: n/a

Goals: Put down an idea I have had for a while onto paper

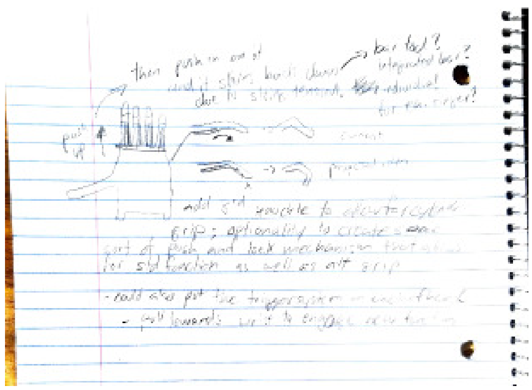
Content:

Picture Below

Conclusions/action items:

Continue brainstorming ways to improve this idea and also start thinking of other possible alternatives.

Matthew Wroblewski - Sep 23, 2021, 12:39 PM CDT



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9/23/2021 Pulley System

Matthew Wroblewski - Oct 17, 2021, 9:16 PM CDT

Title: Pulley System brainstorm

Date: 9/23/2021

Content by: Matthew Wroblewski

Present: N/a

Goals: brainstorm an idea for a pulley system

Content:

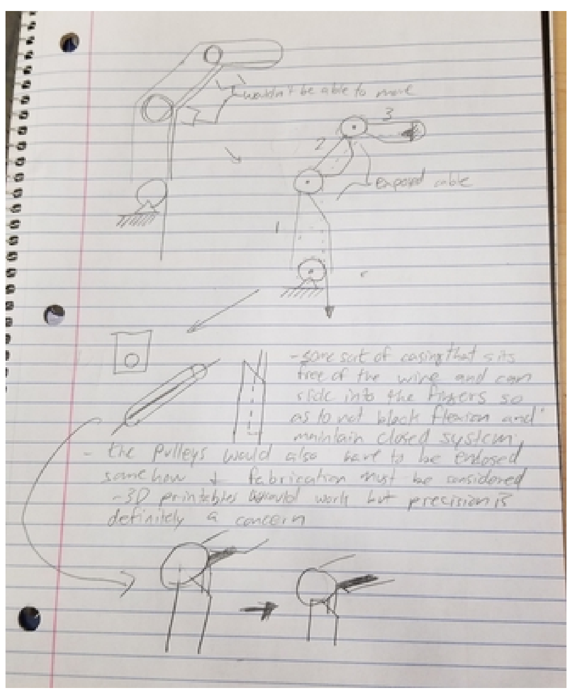
see attachment

Part 2 - Discussed an alternate idea with my brother but decided it would be too complex to make work since the simple design we discussed would not yield a desirable end result after working through some force diagrams

Conclusions/action items:

Continue the research article that I was reading when I created this. Brainstorm more ideas for design matrix next week.

Matthew Wroblewski - Sep 23, 2021, 7:33 PM CDT



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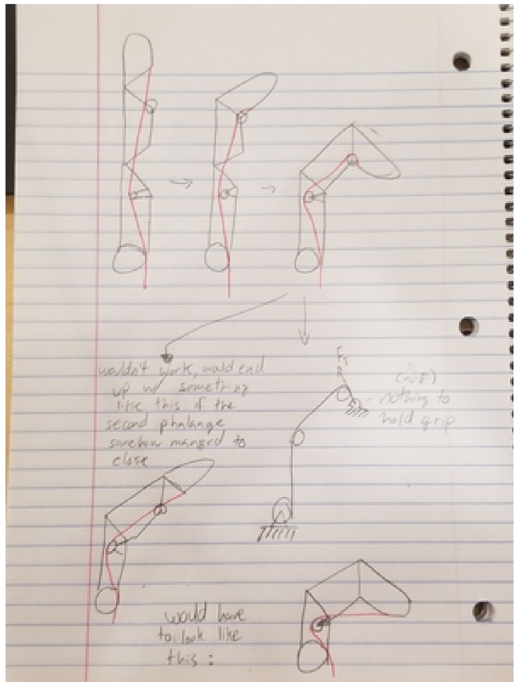
Matthew Wroblewski - Sep 23, 2021, 8:16 PM CDT



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9/26/2021 Questions for Design

Matthew Wroblewski - Sep 27, 2021, 2:54 PM CDT

Title: Questions for design brainstorming session

Date: 9/26/2021

Content by: Matthew Wroblewski

Present: N/a

Goals: Create another brainstormed prototype idea to present to the team tomorrow

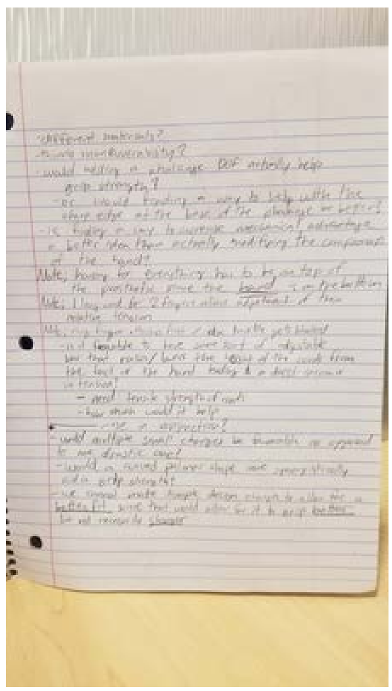
Content:

Sat down to create a new prototype and ended up with a list of questions for how we can make an effective prototype. See below

Conclusions/action items:

Bring up these thoughts with the team when we meet on Monday to see what we want to address as we discuss our ideas.

Matthew Wroblewski - Sep 27, 2021, 2:55 PM CDT



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9/27/2021 Assembly brainstorming

Matthew Wroblewski - Sep 27, 2021, 4:06 PM CDT

Title: Assembly brainstorming

Date: 9/27/2021

Content by: Matthew Wroblewski

Present: n/a

Goals: Think about the construction of the current design as well as the prototype

Content:

- In the current model, there are elastic extensors and non-elastic flexors. The extensors allow for the hand to reliably uncontract after flexion, but naturally due to that nature do remove some grip strength from the system
- To annotate my note about better fits not being stronger from yesterday, I have since realized that a better fit could possibly allow for a "stronger" grip by preventing the object from slipping out as easy, but the mechanics would not actually be any magnitude stronger. I am unsure if this could result in a larger magnitude of grip strength when we test the prosthetics, if it does then problem solved, and if it does not then our testing would be pointless but it could still offer benefits for the user since a better fitting grip is more desirable regardless.
- A way to increase overall tension in the hand could be to adjust the tensioning pins to be able to move forward/backward and thus alter the relative force required from the user to grab an object, but this may result in a more closed nature of the hand rather than one that opens back up.
- Previous ideas I have brainstormed utilized pulley systems but I wonder if we could use gear ratios to our advantage?

Conclusions/action items:

Continue brainstorming ideas and possible complications

9/27/2021 Extra Phalange Design

Matthew Wroblewski - Sep 27, 2021, 4:57 PM CDT

Title: Extra Phalange design brainstorm and tension calculations

Date: 9/27/2021

Content by: Matthew Wroblewski

Present: Alex Vazquez

Goals: Continue brainstorming

Content:

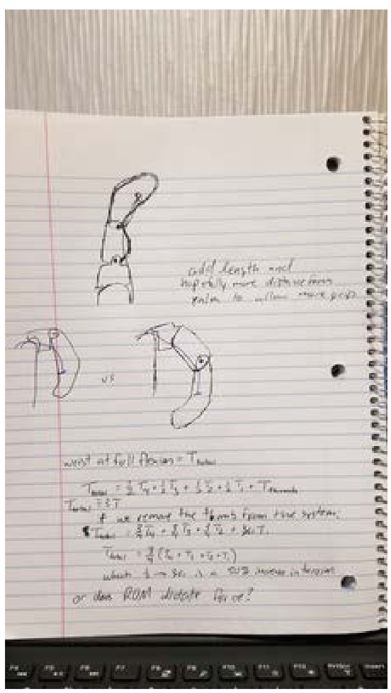
See below:

Other Notes:

- Adding an extra phalange could hypothetically result in a greater distance form the palm

Conclusions/action items:

Matthew Wroblewski - Sep 27, 2021, 4:46 PM CDT



20210927_164426.jpg(2.3 MB) - download

10/10/2021 3 Design Matrix Designs

Matthew Wroblewski - Oct 17, 2021, 9:46 PM CDT

Title: Design Matrix Idea Drawings

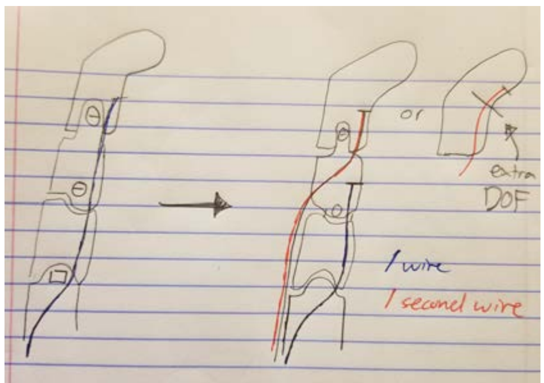
Date: 10/10/2021

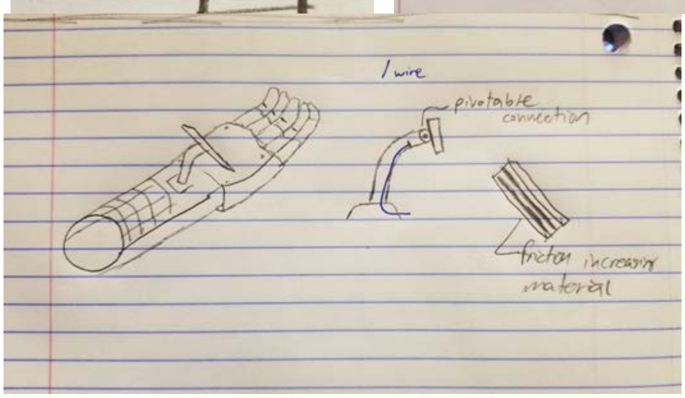
Content by: Matthew Wroblewski

Present: n/a

Goals: Draw out our 3 designs for the PDS to be improved by a team member with digital capabilities at a later date

Content:





Conclusions/action items:

Make sure that everyone on the team understands what each of the designs looks like and then see if someone has the ability to draw them digitally so that they look nicer for the Preliminary Presentation.

10/4/2021 Mesh Conversion

Matthew Wroblewski - Oct 17, 2021, 9:22 PM CDT

Title: Mesh Conversion

Date: 10/4

Content by: Matthew Wroblewski

Present: n/a

Goals: Convert the phoenix reborn model from a mesh to a surface so that we can model with it

Content:

- Attempted to use Fusion 360 to convert the mesh file and convert it into SolidWorks to progress but no success
- Also attempted to use Meshmixer to complete the same task to no avail.
- It was at this time that I presented this information to Sam, who has a lot of experience with 3D modeling already and we decided that it would be best to just proceed forward by creating our own parts from scratch. As a result we may have some alterations to make in the future in order to create a proper fit with our prototype but we will not be wasting time messing around with the .stl files given to us.

Conclusions/action items:

We will now be working a two phase process into our fabrication plan, one where we create a simplified extra phalange to get proof of concept and critical dimensions locked in, then a second phase where we alter the model that we just created to also incorporate the secondary tensioning system.

10/10/2021 Phase 1 Model

Matthew Wroblewski - Oct 17, 2021, 10:55 PM CDT

Title: Phase 1 Model

Date: 10/10/2021

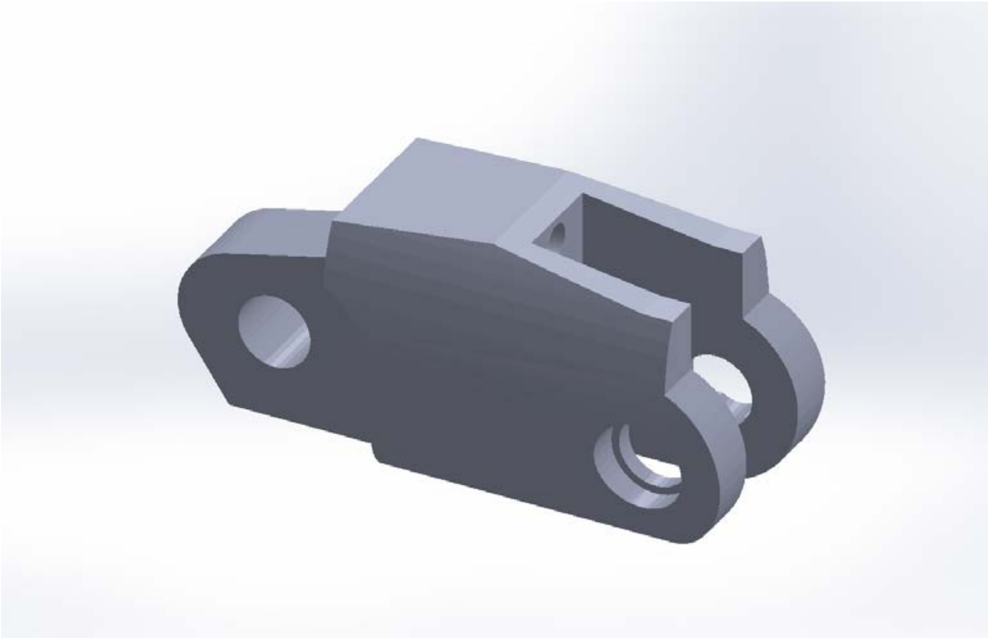
Content by: Matthew Wroblewski (Model by Sam Strachan)

Present: n/a

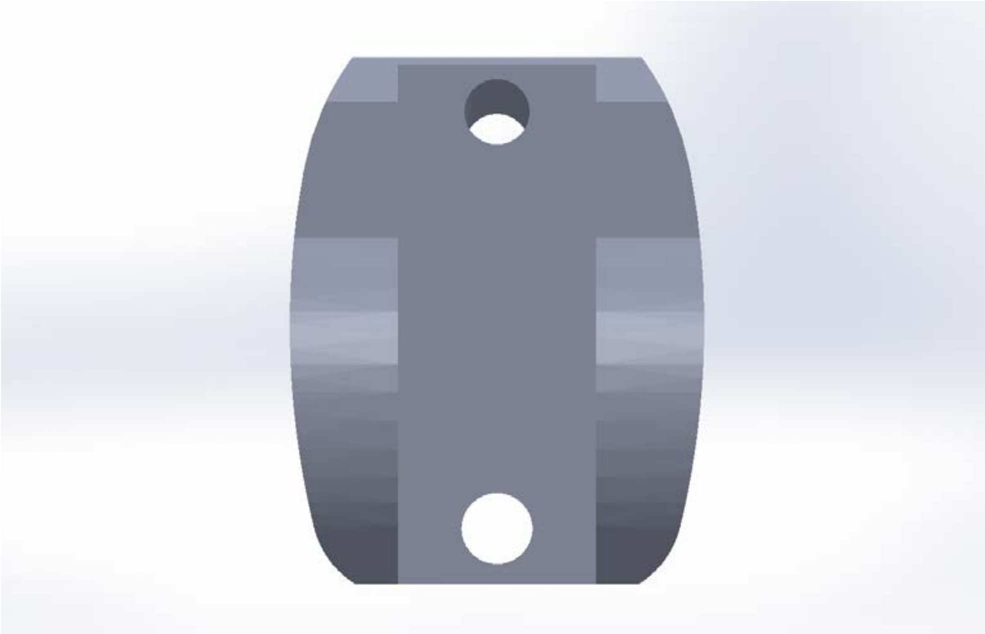
Goals: Upload the 3D Model of our phase 1 Phalange

Content:

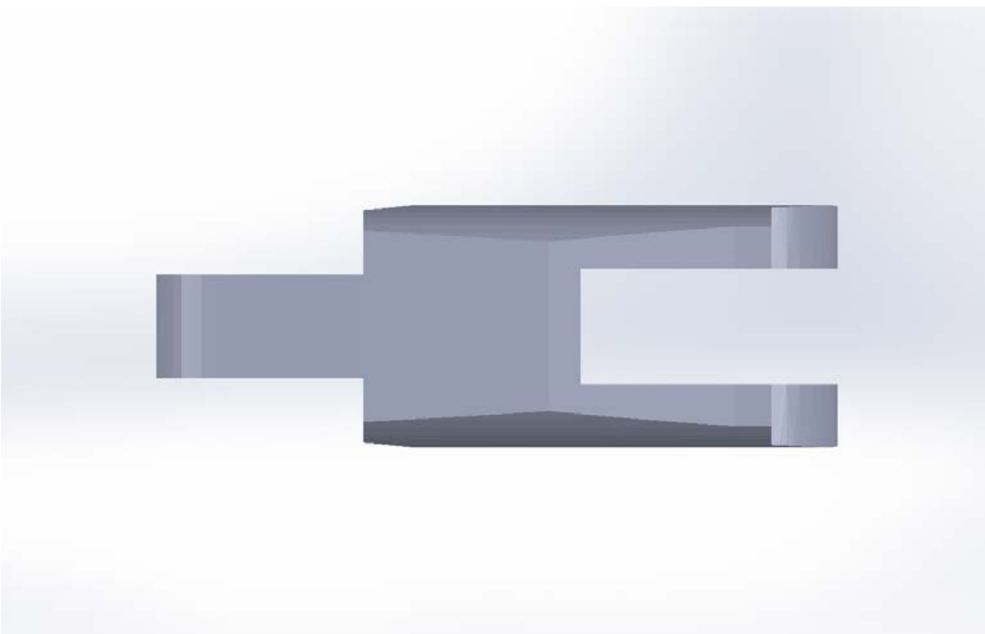
3 Dimensional View:



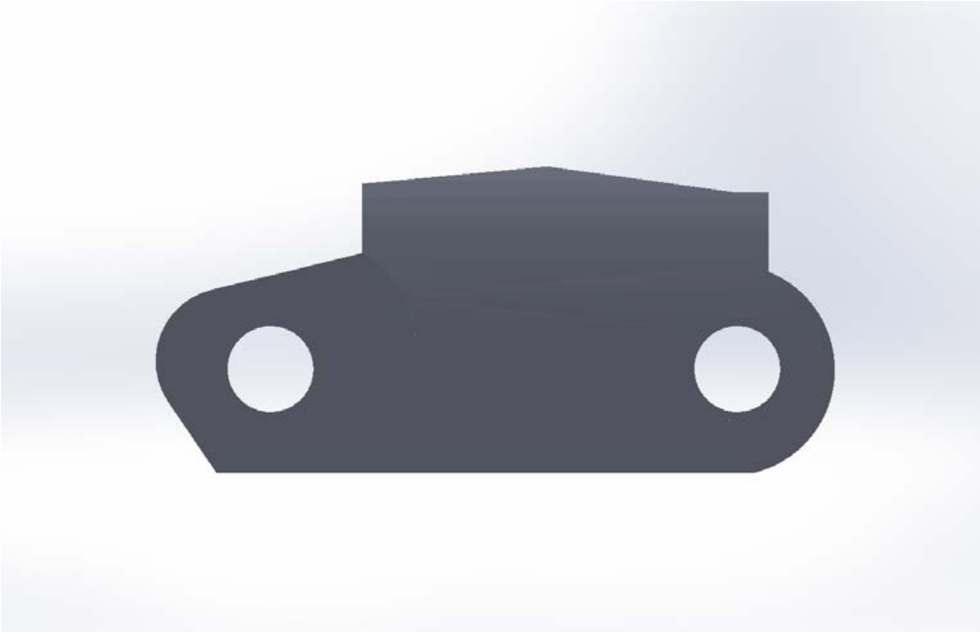
X Directional View:



Y Directional View:



Z Directional View:



Conclusions/action items:

Go to the Makerspace to print the model and then add it to the existing hand that the team has in our possession to see if we need to make alterations before moving forward.

Matthew Wroblewski - Oct 17, 2021, 10:47 PM CDT

Phalange.STL(75.6 KB) - download

10/12/2021 Phase 1 Printing

Matthew Wroblewski - Oct 17, 2021, 10:40 PM CDT

Title: Phase 1 Printing

Date: 10/12/2021

Content by: Matthew Wroblewski

Present: n/a

Goals: Go to the Makerspace and print/clean up our phase 1 phalange extension prototype

Content:


- Post printing pickup from the Makerspace

- Post support removal/clean up
    - Future prints should definitely be oriented the way the picture here is rather than on their side like they were for this print. It creates need for far more supports and ruins the finish on one of the sides. Also, the small holes are particularly difficult to remove supports from. As a result of our part having these small dimensions with low tolerances I talked with Jake, a Fab Fellow at the Makerspace where we talked about the different options besides PLA. Jake informed me that the reason PLA is so frequently used is really just because its really cheap and is pretty durable and that the other printers all offer pretty similar mechanical characteristics so unless we really

needed the print to be PLA, we could use the SLS printer which has soluble supports and then we would not have to worry about it.

Conclusions/action items:

- I will need to look into the filaments offered by the SLS printer, and also what an SLS printer really is. I will also bring this information to the team so that we can discuss what we want to do moving forward in regards to our 3D printing prototypes, since it would be much more time effective for us to use a printer type that requires less post processing by us. In regards to the project, the SLS printer is less applicable for e-NABLE as a whole since they focus more on strictly PLA and you standard filament layering 3D printing techniques, but the end result would be the same and this is just for our own ease of production in order to prove the concept and to get to testing.

11/1 - 11/17 2021 Phase 2 Printing

Matthew Wroblewski - Dec 12, 2021, 1:58 PM CST

Title: Phase 2 Printing

Date: 11/1 through 11/17

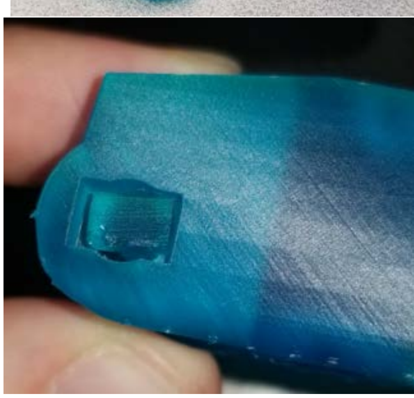
Content by: Matthew Wroblewski

Present: n/a

Goals: Log the team prints and thoughts as we progress through the fabrication process

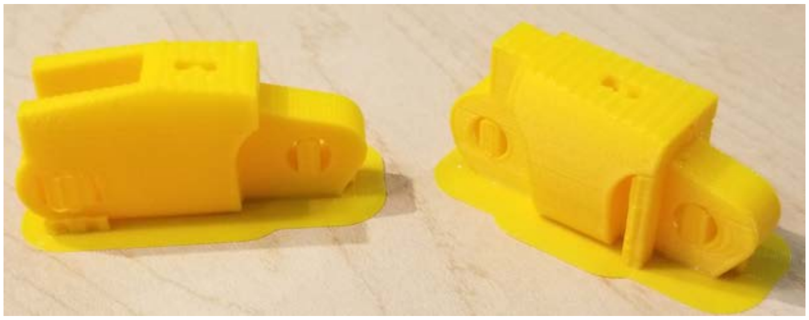
Content:

11/1/2021

- Second print of fabrication, the team used Formlabs Tough Resin to print two phalanx components that were modified in SolidWorks as well as one upscaled pin
- The total cost of the print was $7.58
- The results were mixed very positive and a little bit of failure
- The prints themselves were very high quality with easy to remove supports
- However, the cost of the prints were too much to be aligned with e-NABLE's mantra (and the fact that most people do not have a resin printer) and the pin piece was not upscaled properly
- 
-  

11/5/2021

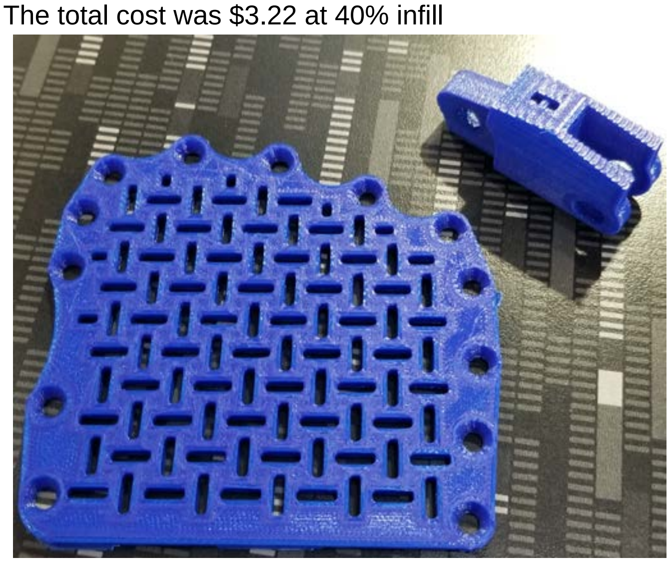
- For the next stage of printing, the model was slightly adjusted to feature a bigger internal diameter pin hole and attempted to be printed in PLA and PVA
- The PLA portion of the print went very well, but unfortunately the supports were also composed of PLA and not PVA

- The total cost of the print was $2.32 at 80% infill
- 

11/12/2021

- With the dimensions honed in and the use of PLA being confirmed feasible, the team printed eight phalanx pieces with PLA using water-soluble PVA supports
- the print overall was a success, but some pieces were a slightly distorted towards the rear, with one piece being unusable
- The total cost was $7.76 at 40% infill
- 
- (See the piece in the second row from the bottom on the left side with the distortion)

11/17/2021

- This should be the last set of printing by the team
- The hand base plate was printed using PLA, and a replacement phalanx piece was printed using PLA with PVA supports again
- The total cost was $3.22 at 40% infill
- 

Conclusions/action items:

Fabrication overall went well with some minor hiccups in the process, the team will now begin to assemble and test the hand

11/19/2021 Testing

Matthew Wroblewski - Dec 12, 2021, 6:36 PM CST

Title: Testing

Date: 11/19/2021

Content by: Matthew Wroblewski

Present: n/a

Goals: log the qualitative testing of the hand

Content:

- The team met up to complete our qualitative testing with the protocol that Kenzie and I worked out
- We used the spreadsheet that Sam designed in accordance with it to quickly generate graphs associated with out testing
- We tested the Red Bull, Bubbly, Arizona Iced Tea, and Hydro Flask with and without grips for both models
- The process took longer than anticipated since we had to walk across the building to adjust the water volumes and use a scale to get precise weights, which was not too much of a time additive, but reassembling the prototype once we finished testing with the original hand took quite a bit longer than expected
- The prototype performed astonishingly and almost managed to pick up the full Hydro Flask, but it could not hold it up steadily so it did not count.

12/2/2021 Quantitative Testing

- Me, Kenzie, and Sam went into my Anatomy & Physiology Lab to use the BIOPAC Lab software's hand dynamometers to gather force values for the hand
- It took me a lot longer to get the program up and running than I thought it would, but this was ok since we had to fix the stringing of the prototype's tensioning system which also took quite a bit longer than expected
- Once the hand was assembled, however, testing ran smoothly and assembling the original hand took very little time so gathering the data was relatively simple
- We were also able to easily gather graphs from the data analysis portion of the software, but found that it did not offer any way to easily export the data so we had to resort to exporting the graphs and then plan for Kenzie to use a graph data analyzer in MATLAB

Conclusions/action items:

We now need to work on data analysis and begin our final report and poster presentation.

11/12/2021 User need and Ethics

Matthew Wroblewski - Dec 12, 2021, 12:55 PM CST

Title: Research to be conducted

Date: 11/12/2021

Content by: Matthew Wroblewski

Present: n/a

Goals: List research articles that I found but did not get to taking notes on beyond finding relevant statistics for the design project

Content:

Literature Review on Needs of Upper Limb Prosthesis Users - https://www.frontiersin.org/articles/10.3389/fnins.2016.00209/full

- 21 DOF in hand, 6 DOF in wrist
- Transcarpal limb loss is what our model is designed more
- Around 541,000 Americans suffered from different levels of upper limb loss in 2005
  - Number cases expected to double at least by 2050
- Approx. 3500 and 5200 upper limb amputations yearly in Italy and UK respectively
  - 61% Transcarpal

Fall Prevalence and Contributors to the Likelihood of Falling in Persons With Upper Limb Loss - DOI: 10.1093/ptj/pzy156

- Unilateral arm swing restriction in healthy adults leads to increased contralateral arm swim to compensate and maintain coordinating
- bilateral arm swim reduction increased metabolic cost of walking
  - could impair stability and increase fall risk through fatigue
  - extends to running as well
- Poor upper limb prosthetic embodiment has been shown to impair postural control suggesting that particular models may impair stability
- Prosthetic may be unable to quickly stop an individual if they fall by grabbing onto something
- Individuals could be at greater risk for a fall when the device is used to counteract a disturbance (grasping/bracing/supporting) when the device is not intended for that purpose
- 30% of falls occur on stairs, 30% also occur walking outdoors
- Loss of balance is responsible for 27% of falls
- 55% of falls were categorized as intrinsic

This article in particular garners questions about the ethicality of our project, given that weight distribution is so important to proper locomotion and coordination while individuals are walking. Our prototype will not only be heavier than the existing models due to our extensions, but will also feature longer fingers that are much less suited to catching on a sharp edge than the previous model. The increased strength may allow the model to better catch, but we must consider the ethicality of creating a model that could inherently increase the risk of injury by fall in the potential users.

This is especially important to consider its impact on elderly users, who are at greater risk of serious injury from a fall and are also typically most acclimated to their previous weight distributions in life and may have trouble adjusting to a model that is of increased size and weight.

Estimating the Prevalence of Limb Loss in the United States: 2005 to 2050 - https://doi.org/10.1016/j.apmr.2007.11.005

- in 2005, 1.6 million persons were living with the loss of a limb
    - 38% had an amputation secondary to dysvascular disease via diabetes mellitus
    - projected number of people 3.6 million by 2050
        - could be lowered by 225,000 with 10% less rates of dysvascular disease
- In the U.S. an estimated 185,000 persons undergo an amputation of an upper or lower limb each year
- Difficult to predict since NHIS no longer questions about upper or lower extremity loss

Table 1. Age-Specific Estimates of Prevalence by Sex, Race and Ethnicity, and Etiology (in thousands): Year 2005, United States

Etiology, Sex, and Race and Ethnicity	All Ages	Under 65 Years				65 Years and Over		
		Total	**Under 18**	**18–44**	**45–64**	**Total**	**65–74**	**75–100**
All etiologies	1568	903	25	277	601	665	323	342
Sex								
Male	1026	668	16	218	433	358	199	159
Female	542	235	9	58	168	306	124	183
Race and ethnicity								
Nonwhite women	195	92	4	23	65	103	47	56
Nonwhite men	457	313	9	113	190	145	83	61
White women	347	143	5	35	104	203	76	127
White men	569	355	7	105	243	214	116	98
Dysvascular disease: total								
Total	846	375	2	52	321	471	228	242
Nonwhite women	151	59	*	8	50	92	42	50
Nonwhite men	185	101	*	17	84	84	50	34
White women	249	82	*	10	71	167	63	104
White men	261	133	*	17	116	128	73	54
Dysvascular disease with comorbidity of diabetes								
Total	592	191	*	18	174	400	162	239
Nonwhite women	106	31	*	3	28	75	28	47
Nonwhite men	146	60	*	6	54	86	44	42

Etiology, Sex, and Race and Ethnicity	All Ages	Under 65 Years				65 Years and Over		
		Total	Under 18	18–44	45–64	Total	65–74	75–100
White women	164	54	*	5	49	110	44	66
White men	176	47	*	4	43	129	45	84
Trauma								
Total	704	513	22	218	273	192	93	99
Nonwhite women	41	30	3	14	14	11	5	6
Nonwhite men	270	209	9	95	105	61	33	28
White women	92	57	4	23	30	35	13	22
White men	301	216	6	86	124	85	42	43
Cancer								
Total	18	15	*	7	7	3	2	*
Nonwhite women	3	2	*	1	*	*	*	*
Nonwhite men	3	3	*	1	*	*	*	*
White women	6	5	*	2	2	1	*	*
White men	7	6	*	2	3	*	*	*

NOTE. Totals may not equal sum because of rounding.

*
Represents less than 1000.

Prosthesis use in persons with lower- and upper-limb amputation -

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2743731/

- Approximately 84 percent of persons with LLA and 56 percent of persons with ULA reported using a prosthesis for a mean ± SD of 12.47 ± 4.34 and 10.67 ± 5.00 hours per day, respectively.
- greater prosthetic use (hours/day) was significantly associated with proximal amputations in persons w/ ULA
- greater prosthetic use (days/moth) was significantly associated with distal amputations in persons w/ ULA
    - i.e. distal wears almost every day, and proximal wears it less often but for nearly the entire day when they do
- Prosthesis use was unrelated to the perception that prosthesis use affects pain

Conclusions/action items:

These articles have a lot of relevant and useful information for our design project that we should take into consideration, especially the ethics of our design as I wrote above.

12/12/2021 Societal Impact

Matthew Wroblewski - Dec 12, 2021, 1:18 PM CST

Title: Societal Impact

Date: 12/12/2021

Content by: Matthew Wroblewski

Present: N/A

Goals: Go over my thoughts on the societal impact of the hand and some of the ethical considerations of the project

Content:

- The hand was able to stay low cost and affordable for those individuals in need which helps the project stay aligned with the core values of e-NABLE and their outreach to global communities, particularly those in developing nations
- The low cost nature means that for those individuals that wish to have a prosthetic much better suited to gripping cylindrical objects in their everyday life, the prototype may be a good fit for them and can be easily maintained and replaced in the events of breaks/growth resulting in the hand no longer fitting properly.
- The team still needs to remain conscientious of the ethical implications of our project since it may have the potential to contribute to greater incidence of falls in users as a result of the increased weight of the hand leading to increased walking and running arm swing compensation.
    - Possible increased injury as a result of fall with the hand not properly bracing or causing irregularities in the nature of the fall should also be considered
    - This applies to all prosthetic hands and almost appears as an inherent risk for the gains of use of the prosthetic, but we still must remain conscious of it and find ways to work around the increased size and length of the model in the future, with perhaps shortening the extensions to a closer length matching how the original hand only had one phalanx piece.
- The increased strength of the model should be a benefit to users, increasing the overall capabilities of the hand

Conclusions/action items:

The team hopes that our improved design can be introduced to the e-NABLE, approved, improved, and adopted into common models to help those individuals in need around the world.

2021/09/19- Basic research

ALEXANDER VAZQUEZ - Sep 27, 2021, 3:02 PM CDT

Title: General Research

Date: 2021/09/19

Content by: Alex

Present: Alex

Goals: Gain a better understanding of prosthetics and some potential issues.

Content:

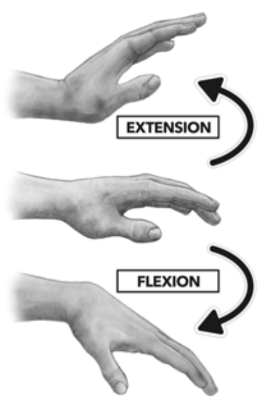
Salminger, S., Roche, A. D., Sturma, A., Mayer, J. A., & Aszmann, O. C. (2016). Hand Transplantation Versus Hand Prosthetics: Pros and Cons. *Current surgery reports*, *4*, 8. https://doi.org/10.1007/s40137-016-0128-3

https://www.amputee-coalition.org/resources/prosthetic-faqs-for-the-new-amputee/

Complications with prosthetics.

- **Reduced overall function of hand**
- **Discomfort of prosthetic**
- **Cost of prosthetic**
- **Prosthetics can be limiting in what activities you can do**
- **You can outgrow prosthetics**
- **More intensive prosthetics require an insert to attach them**
    - **This can cause some discomfort over time**

Many logistical issues arise when dealing with prosthetics (cost, maintenance, etc.) but the more important factors are how it interacts with the user. It is important that the prosthetic is made out of materials that will not irritate the skin so that user discomfort is minimized. In the case of the E-Nable prosthetic, soft materials should be used so that while in use the prosthetic fulfills that target. Another physiological concept required to be looked at would be the necessity to prevent user fatigue. This results as there is only one degree of motion while using E-Nables prosthetic which would be movement of the wrist up and down (Pictured below). While carrying some weight with the prosthetic, it is possible for the user to become tired of this position and require a rest.



Conclusions/action items:

Understanding different complications that arise while the human body interacts with a prosthetic is imperative to solve these issues. Solving the issues results in a better overall product and user satisfaction.

2021/09/19- Hand Replacement Alternative

ALEXANDER VAZQUEZ - Sep 27, 2021, 2:21 PM CDT

Title: Competing Idea Research

Date: 2021/09/19

Content by: Alex

Present: Alex

Goals: Identify possible alternatives that could be used instead of E-Nables prosthetic hand

Content:

Salminger, S., Roche, A. D., Sturma, A., Mayer, J. A., & Aszmann, O. C. (2016). Hand Transplantation Versus Hand Prosthetics: Pros and Cons. *Current surgery reports*, *4*, 8. https://doi.org/10.1007/s40137-016-0128-3

One alternative that this article introduces is a donor hand. This is then attached to the amputee to mimic a functional hand. The main advantage of this procedure is that it is very functional. It restores some feeling and motor functions of the hand to the amputee. This is very important from a comfort standpoint as it would look and function similarly to the original hand and there would be minor adjustments to get used to .

The main drawbacks of this procedure would be that immunosuppressants are required to make sure the body does not reject the new hand. This also comes with the negative side effects of the immunosuppressant in the long term such as increased risk of infections and organ failures. This with the long term need for physical therapy makes it a very intensive option that will require a lot of work to complete.

Conclusions/action items:

Overall this procedure may be good for someone who is an adult (done growing) and wants to obtain/retain some original use of their hand. This would not be good for a child who is still growing or someone who works with their hands in harsh environments. A better alternative would be a cheaper temporary prosthetic that can be easily/cheaply replaced.

2021/12/12- Society Impacts and Considerations

ALEXANDER VAZQUEZ - Dec 14, 2021, 5:58 PM CST

Title: Societal Impacts and Considerations

Date: 2021/12/12

Content by: Alex

Present: Alex

Goals: Look at how this product will impact people

Content:

- Two types of limb loss
    - Congenital (From birth)\
    - Other trauma or health related issues
        - Largely caused by vascular diseases (diabetes)
- Projected to be about 3.6 million people with limb loss by 2050 within the US
- WHO estimates ~30 million are in need of prosthetic but do not have access to established prosthetic/orthotic programs
    - Largely due to high costs of these programs
- Prosthetic need maintenance which can be expensive

Implications for our design:

Through our project we are able to provide a cheaper and more accessible alternative to more expensive prosthetics. As the population of patients with limb loss continues to grow, the expected demand will increase. By providing a design that is easier to manufacture, we could more effectively provide people with an increased quality of life. The other important implication of our design is that it can be produced for countries that lack established prosthetic programs.

Sources:

"Facts about limb loss," *Shirley Ryan AbilityLab*. [Online]. Available: https://www.sralab.org/research/labs/bionic-medicine/news/facts-about-limb-loss#:~:text=The%20World%20Health%20Organization%20estimates,poorer%20clinical%20coverage%20of%20patients. [Accessed: 14-Dec-2021].

Conclusions/action items:

Providing a cost effective and easy to manufacture prosthetic can be beneficial to both afflicted people in the US and those who do not have access to other products.

2021/09/15- Design Ideas

ALEXANDER VAZQUEZ - Oct 19, 2021, 4:41 PM CDT

Title: Potential design Ideas

Date: 2021/09/15

Content by: Alex

Present: Alex

Goals: Bainstorm Potential Ideas

Content:

Possible ideas for improvement:

1. Mechanism for thumb to move/ rotate to allow for different grips.
2. Introduce new materials to increase tension and increase grip
3. Hydrolyic/pneumatic additions?
4. Possibly electronics
5. Pulley system

Conclusions/action items:

Continue Brainstorming, present ideas with group, and draw out potential designs.

2021/09/22- Testing Basis/Criteria

ALEXANDER VAZQUEZ - Oct 19, 2021, 5:33 PM CDT

Title: Testing Method

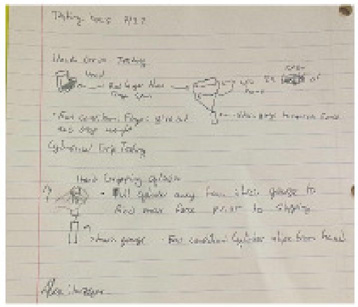
Date: 09/22

Content by: Alex

Present: Alex

Goals: Understand Testing Criteria given to us by the client

Content:



- In both cases max achieved force is recorded as data.
- Possibly include time till failure as a data point

Conclusions/action items:

Bring up any testing logistical concerns with the group and client.

Testing_basis.pdf(351.9 KB) - download

2021/09/24- Potential Design Alternatives

ALEXANDER VAZQUEZ - Oct 19, 2021, 5:42 PM CDT

Title: Design Alternatives

Date: 2021/09/24

Content by: Alex

Present: Alex

Goals: Find alternative materials to add to existing design and present a remodeling design

Content:

Main components with replaceable materials

- Tension cords in fingers
  - Implementing tension cords would allow for a system to use the elasticity of the cord for more flexibility
  - This could help increase the overall grip that the hand has on the object itself
  - The springiness of the cord would increase the force the user needs to input as it would be absorbed by the string
- Tactile grip material on fingers
  - Using a different, more "sticky" material on the fingertips would allow for the hand to form a more stable grip to the object itself
  - This allows for a lower overall grip strength of the prosthetic and a lower input force from the user
- 3d printer material
  - Using a lighter/stronger composition of material would help prevent the design from breaking under use with an increased grip strength
  - Making the overall design lighter also decreases the chances of the user becoming fatigued while using the prosthetic
- Implement a pulley system to decrease user input force
  - Use mechanical advantage to decrease users exertion while prosthetic is in use.
- Thumb repurposing
  - Conversion of the thumb into a rotatable anchor point to help secure held objects

Design_Ideas.pdf(389.4 KB) - download

2021/10/28- Updated Testing Ideas

ALEXANDER VAZQUEZ - Dec 14, 2021, 5:03 PM CST

Title: Testing Method

Date: 10/28

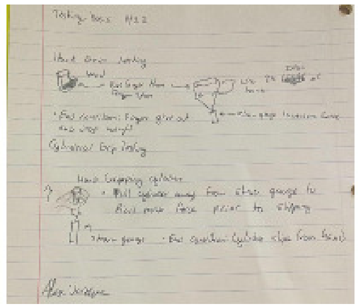
Content by: Alex

Present: Alex

Goals: Develop a quantitative testing method for the prosthetic

Content:

(From precious notebook entry)



- In both cases max achieved force is recorded as data.
- Possibly include time till failure as a data point

Updated_testing.pdf(371.1 KB) - download

2021/21/04- Testing Results

ALEXANDER VAZQUEZ - Dec 14, 2021, 5:27 PM CST

Title: Testing Conductions

Date: 2021/12/04

Content by: Alex

Present: Team

Goals: Finish testing (Quantitate and Qualitative)

Content:

Qualitative:

- Methods:

    - Obtain objects with 4 different diameters (Redbull, soda can, Arizona tea and hydro flask)

    - Attempt to grip and lift object with base hand, base hand with grips (Rubber page turners), new design and new design with grips

    - If hand successfully lifts each object, mark as success, if not, mark as failure, filled in Sam's document

    - Fill objects with water to test ability to lift

- Results

    - Base hand performed the worst and the modified hand performed best with grips

    - Overall the increase length of the fingers allowed the hand to more effectively wrap around the object that was being gripped.

    - The finger grips increased performance by increasing surface friction between the objects and the hand itself

Quantitative:

- Methods:

    - Use base hand and modified hand to grip hand dynamometer to map out its ability to exert forces.

Conclusions/action items:

2021/09/14-Differences in MYO and BP Prostheses

KENZIE HURT - Sep 14, 2021, 6:05 PM CDT

Title: Differences in Myoelectric and Body-Powered Upper-Limb Prostheses

Date: 2021/09/14

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To gain background on the benefits of body-powered prosthesis.

Search term: PubMed: body powered prosthetic

Citation: Carey, Stephanie L et al. "Differences in myoelectric and body-powered upper-limb prostheses: Systematic literature review." Journal of rehabilitation research and development vol. 52,3 (2015): 247-62. doi:10.1682/JRRD.2014.08.0192

Link: **https://www.rehab.research.va.gov/jour/2015/523/pdf/JRRD-2014-08-0192.pdf**

Content:

- This is a systematic literature review and compiled information from many different designs.
- The main difference between MYO and BP prostheses are the way they are controlled as MYO uses signals and BP utilizes the individual's physical movement.
- There are many mixed reviews about which is the better route to go as there are different factors that go into people's choices.
- If the extremity was there at birth and then lost later in life due to any circumstances, the review suggests that BP prostheses are much easier to start with as there is little training that goes into it. Since there was already use of the extremity throughout life, moving the extremity up to the point of amputation is still very accessible as they've had strong muscle control.
- The BP prostheses are also more durable and easier to maintain.
- Using physiology and known muscle movements of the extremity, BP prostheses can be stronger as it is being physically controlled by the individual.

Conclusions/action items:

The e-NABLE prostheses utilize the BP design which allows for a low cost, stronger, maintainable, and more durable prosthetic for the individuals. By utilizing anatomy and muscles that have already been in use, there is very little to no training to start using the prosthetic.

KENZIE HURT - Sep 14, 2021, 6:06 PM CDT

JRRD Volume 52, Number 3, 2015
Pages 247–262

Differences in myoelectric and body-powered upper-limb prostheses: Systematic literature review

Stephanie L. Carey, PhD;[1*] Derek J. Lura, PhD;[2] M. Jason Highsmith, DPT, PhD, CP, FAAOP[3]
[1]Department of Mechanical Engineering, University of South Florida, Tampa, FL; [2]Department of Bioengineering and Software Engineering, U.A. Whitaker College of Engineering, Florida Gulf Coast University, Fort Myers, FL; [3]School of Physical Therapy & Rehabilitation Sciences, Morsani College of Medicine, University of South Florida, Tampa, FL

Abstract—The choice of a myoelectric or body-powered upper-limb prosthesis can be determined using factors including control, function, feedback, cosmesis, and rejection. Although body-powered and myoelectric control strategies offer unique functions, many prosthesis users must choose one. A systematic review was conducted to determine differences between myoelectric and body-powered prostheses to inform evidence-based clinical practice regarding prescription of these devices and training of users. A search of 9 databases identified 462 unique publications. Ultimately, 31 of them were included and 11 empirical evidence statements were developed. Conflicting evidence has been found in terms of the relative functional performance of body-powered and myoelectric prostheses. Body-powered prostheses have been shown to have advantages in durability, training time, frequency of adjustment, maintenance, and feedback; however, they could still benefit from improvements of control. Myoelectric prostheses have been shown to improve cosmesis and phantom-limb pain and are more accepted for light-intensity work. Currently, evidence is insufficient to conclude that either system provides a significant general advantage. Prosthetic selection should be based on a patient's individual needs and include personal preferences, prosthetic experience, and functional needs. This work demonstrates that there is a lack of empirical evidence regarding functional differences in upper-limb prostheses.

Key words: amputation, artificial limb, control, cosmesis, external power, function, prosthesis, rehabilitation, transhumeral, transradial.

INTRODUCTION

In 2005, an estimated 1.6 million people in the United States were living with an amputation. This number is expected to increase to over 2.3 million by 2020 [1]. A more recent report already estimates an increase to 1.7 million people in just over 3 yr [2]. A retrospective study examining amputations sustained by U.S. servicemembers from January 2001 through July 2011 reported that 14 percent of amputations involved the upper limb and that 10 percent of these involved more than one amputation [3]. In 2004, interviews with members of the Amputee Coalition of America found nearly one-third of persons with amputation reported being dissatisfied with

Abbreviations: AAOP = American Academy of Orthotists and Prosthetists, ADL = activity of daily living, BP = body-powered, EES = empirical evidence statement, EMG = electromyography, fMRI = functional magnetic resonance imaging, MYO = myoelectric, OIF/OEF = Operation Iraqi Freedom/Operation Enduring Freedom, ROM = range of motion, SHAP = Southampton Hand Assessment Procedure, TD = terminal device.

*Address all correspondence to Stephanie L. Carey, PhD; University of South Florida, Department of Mechanical Engineering, 4202 E. Fowler Ave, ENB 118, Tampa, FL 33612; 813-974-5785; fax: 813-974-3539. Email: [illegible]

http://dx.doi.org/10.1682/JRRD.2014.08.0192

JRRD-2014-08-0192.pdf(304.1 KB) - download

2021/09/14-Motor Learning for Prosthesis Training

KENZIE HURT - Sep 14, 2021, 8:57 PM CDT

Title: Kinematic Analysis of Motor Learning in Upper Limb Body-Powered Bypass Prosthesis Training

Date: 2021/09/14

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To gain background on the physiology of using a prosthetic as a novel user and also the training behind use.

Search term: PubMed: body powered prosthetic biomechanics

Citation: Bloomer, Conor et al. “Kinematic analysis of motor learning in upper limb body-powered bypass prosthesis training.” PloS one vol. 15,1 e0226563. 24 Jan. 2020, doi:10.1371/journal.pone.0226563

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6980621/

Content:

- A body powered prosthetic was used experimentally with able bodied subjects where the prosthetic was adapted to fit an able bodied subject (bypassing physical loss of an extremity) to simulate a novel user of a prosthetic like someone who had just lost an extremity.
- Individuals who were able bodied then went through a loss of an extremity, they have developed motor control with the extremity up until they lost it. Understanding how motor control is changed after that loss and compensational behaviors developing, it can help discover ways BP prostheses can be improved to minimize stress and training.
- The study was done using a within-subject paradigm across two training times assessing prosthesis trainman through functional, kinematic, and kinetic analyses. The joints that were evaluated through this study were the shoulders, torso and right elbow.
- Two tests were performed after 5 training sessions then again after 10. The movement parameters that were assessed included: time to complete tasks, normalized jerk of joints, changes in efficiency and compensation parameters to complete tasks, and meaning the joints' range of motion, maximum angle and average moment.

Conclusions/action items:

By understanding how loss of extremities can affect one's motor control, compensation tendencies, and frustration without something that was once there, one can use this information to better help with occupational training while also finding aspects of prosthetics that are lacking or could be improved.

KENZIE HURT - Sep 14, 2021, 6:13 PM CDT

PLOS ONE

RESEARCH ARTICLE

Kinematic analysis of motor learning in upper limb body-powered bypass prosthesis training

Conor Bloomer[1], Sophie Wang[1,2], Kimberly Kontson[1]*

1 Division of Biomedical Physics, Food and Drug Administration, Silver Spring, Maryland, United States of America, 2 Department of Bioengineering, University of Maryland, College Park, Maryland, United States of America

* [illegible]

Abstract

Motor learning and compensatory movement are important aspects of prosthesis training yet relatively little quantitative evidence supports our current understanding of how motor control and compensation develop in the novel body-powered prosthesis user. The goal of this study is to assess these aspects of prosthesis training through functional, kinematic, and kinetic analyses using a within-subject paradigm compared across two training time points. The joints evaluated include the left and right shoulders, torso, and right elbow. Six able-bodied subjects (age 27 ± 3) using a body-powered bypass prosthesis completed the Jebsen-Taylor Hand Function Test and the targeted Box and Blocks Test after five training sessions and again after ten sessions. Significant differences in movement parameters include [illegible] times to complete tasks, reduced normalized jerk for most joints and tasks, and more variable changes in efficiency and compensation parameters for individual tasks and joints measured as range of motion, maximum angle, and average moment. Normalized jerk, joint specific path length, range of motion, maximum angle, and average moment are presented for the first time in this unique training context and for this specific device type. These findings quantitatively describe numerous aspects of motor learning and control in able-bodied subjects that may be useful in guiding future rehabilitation and training of body-powered prosthesis users.

OPEN ACCESS

Citation: [illegible]

Editor: [illegible]

Received: May 1, 2019

Accepted: November [illegible], 2019

Published: January [illegible], 2020

Data Availability Statement: [illegible]

Funding: [illegible]

Introduction

Upper limb amputees experience well-documented and self-reported disability, loss of function, and overuse injury with the loss of the upper extremity [1,2]. With this loss, individuals are faced with adapting and relearning aspects of motor control with the reduced or less easily controlled degrees of freedom (DOFs) of a prosthetic device. While the functional and motor performance of other rehabilitation patient populations have been studied extensively (e.g. stroke [3–5]), the dynamic progress and motor learning of upper limb amputees has been relatively neglected. Meanwhile, an emergence of quantitative movement-based measures, enabled

pone.0226563.pdf(1.9 MB) - download

2021/10/19-Biomechanics of the Hand

KENZIE HURT - Oct 19, 2021, 9:59 PM CDT

Title: Biomechanics of the Hand

Date: 2021/10/19

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To gain background on the physiology of the human hand.

Search term: google-biomechanics of hand

Citation: D. Thompson, "Biomechanics of the Hand," ouhsc, 11-Jul-2001. [Online]. Available: https://ouhsc.edu/bserdac/dthompso/web/namics/hand.htm. [Accessed: 19-Oct-2021].

Link: https://ouhsc.edu/bserdac/dthompso/web/namics/hand.htm

Content:

- Abbreviations used in the website: metacarpo-phalangeal (MP), proximal interphalangeal (PIP), distal interphalangeal (DIP), flexor digitorum profundus (FDP), flexor digitorum superficialis (FDS), extensor digitorum comunis (EDC), oblique retinacular ligament (ORL)
- There are several tendinous structures that comprise the extensor mechanism: extensor digitorum tendon, central tendon, lateral bands, and the hood region
- The EDC tendon attaches to the proximal phalanx, extending the MP joint
- the central tendon proceeds dorsally attaching to the base of the middle phalanx - tension can extend the PIP joint
- lateral bands proceed on either side of dorsal midline and rejoin to attach to the distal phalanx - tension in lateral bands extend the DIP joint
- extensor hood surrounds the MP joint laterally, medially, and dorsally
- fibers of ORL attach on sides of proximal phalanx and digital tendon sheaths and run to distal portion of lateral bands - line of application is polar to PIP joint's lateral axis and dorsal to the DIP joint's lateral axis
- PIP extension elongates ORL - creates passive tension extending DIP which helps to open the hand
- DIP flexion elongates ORL - creates passive tension that flexes the PIP which assists in fingers closing

Conclusions/action items:

By understanding how an anatomical hand works biomechanically, it can help us when trying to figure out a more complex tensioning system. We can play to the anatomical strengths the hand already uses biomechanically and apply them to the prosthetic to simulate the way an anatomical hand moves.

KENZIE HURT - Oct 19, 2021, 9:23 PM CDT

Biomechanics_of_the_Hand.pdf(147 KB) - download

2021/10/19-Grasping Force Optimization

KENZIE HURT - Oct 19, 2021, 9:59 PM CDT

Title: Grasping Force Optimization Approaches for Anthropomorphic Hands

Date: 2021/10/19

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To gain background on the mechanics of different grips and the forces utilized during grasping of objects.

Search term: google scholar - grasping force hand

Citation: Cloutier, A., and Yang, J. (December 20, 2017). "Grasping Force Optimization Approaches for Anthropomorphic Hands." ASME. J. Mechanisms Robotics. February 2018; 10(1): 011004. https://doi.org/10.1115/1.4038684

Link: https://asmedigitalcollection.asme.org/mechanismsrobotics/article/10/1/011004/377208/Grasping-Force-Optimization-Approaches-for

Content:

- To achieve a balanced grasp of an object, there must be carefully chosen forces with a certain magnitude to make sure that the force is not too strong where it could crush the object but also for it to not be too weak where the object could slip out of the hand
- Grasping force optimization has been hard to compare between subjects as there are different types of grips, different grasping devices, the differences in objects being grasped and the contact model
- This study focused on three grip types known as the cylindrical grasp, tip grasp, and tripod grasp utilizing different type of finger frictions (namely soft finger and hard finger contact friction models)
- Both nonlinear and linear matrix inequality approaches perform well in terms of accuracy where nonlinear method performs quicker

Conclusions/action items:

This is slightly different for what we will use when deciphering how we want to apply forces to an object. This was done for robotic grasping, however, our prosthetic will be used by a person that controls the force of grasping objects. We can use the data and analyzation of the cylindrical grasp from this study to think about how we may apply this to our project.

KENZIE HURT - Oct 19, 2021, 9:36 PM CDT


Grasping Force Optimization Approaches for Anthropomorphic Hands

Aimee Cloutier

James Yang

Introduction

Journal of Mechanisms and Robotics Copyright © 2018 by ASME FEBRUARY 2018, Vol. 10 / 011004-1

Grasping_Force_Optimization_Approches_for_Anthropomorphic_Hands.pdf(1012.3 KB) - download

2021/10/19-The Anatomy and Mechanics of the Human Hand

KENZIE HURT - Oct 19, 2021, 9:59 PM CDT

Title: The Anatomy and Mechanics of the Human Hand

Date: 2021/10/19

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To gain background on the mechanics of how the hand works anatomically.

Search term: google scholar - physiology of hand

Citation: C. L. Taylor and R. J. Schwarz, “The Anatomy and Mechanics of the Human Hand,” Orthotics and Prosthetics. [Online]. Available: http://www.oandplibrary.org/al/pdf/1955_02_022.pdf. [Accessed: 19-Oct-2021].

Link: http://www.oandplibrary.org/al/pdf/1955_02_022.pdf

Content:

- This journal shows the anatomy of the hand including all bones, tendons, ligaments, joints and muscles that control and make up the hand
- It talks about how each joint articulates and also discusses how they articulate in relation to one another
- The virtual center of rotation lies approximately at the center of curvature of the distal end of the proximal member
- Lateral aspects of the joint surfaces are narrowed and closely bound with ligaments resulting in small lateral rotation in metacarpophalangeal joints lacking entirely in phalangeal articulations
- Results in typical hinge joints
- The thumb is different since it is lacking the second phalanx, and there is also greater mobility in the carpometacarpal articulation allowing for circumduction
- Each phalanx segment has virtual centers of rotation, however, when they come together it results in the overall center of curvature to the distal end of the proximal member
- When hand is cupped for spherical prehension, the opponens muscles of the thumb and little finger (aided by other adductors and flexors) act to pull these digits toward each other resulting in the same motion as when a fist is made

Conclusions/action items:

By utilizing the information presented above, especially the last bullet point, we can try to apply these anatomical mechanics of the hand to our prosthetic. The last bullet is especially important because we can use the way the thumb and little finger move in relation to each other for increasing grip strength.

KENZIE HURT - Oct 19, 2021, 9:55 PM CDT

The Anatomy and Mechanics of the Human Hand

CRAIG L. TAYLOR, Ph.D.,[1] AND
ROBERT J. SCHWARZ, M.D.[2]

It is obvious to all that the human hand represents a mechanism of the most intricate fashioning and one of great complexity and utility. But beyond this it is intimately correlated with the brain, both in the evolution of the species and in the development of the individual. Hence, to a degree we "think" and "feel" with our hands, and, in turn, our hands contribute to the mental processes of thought and feeling.

In any mechanism, animate or inanimate, functional capabilities relate both to structural characteristics and to the nature of the control system available for management of functions singly or in multiple combinations. Just so with the human hand. Analysis of normal hand characteristics therefore requires an understanding of both sensory and mechanical features. Of course whole volumes have been written on hand anatomy, and it is not possible in a short article to describe all elements in detail. It is helpful, however, to review the basic construction of bones and joints and of the neuromuscular apparatus for governing motions and forces. Twenty-four muscle groups, controlled by the various motor and sensory nerve pathways, with their rich potentialities for central connection, and acting upon a bone and joint system of great mechanical possibilities, give to the hand its capacity for innumerable patterns of action.

THE FUNCTIONAL STRUCTURE OF THE HAND

THE BONES

The bones of the hand, shown in Figure 1, naturally group themselves into the carpus, comprising eight bones which make up the wrist and root of the hand, and the digits, each composed of its metacarpal and phalangeal segments (Table 1). The carpal bones are

Table 1

BONES AND JOINTS OF THE HAND AND WRIST

Carpal bones	
GM.	Greater multangular
N.	Navicular
L.	Lunate
T.	Triquetrum
P.	Pisiform
LM.	Lesser multangular
C.	Capitate
H.	Hamate
Metacarpal bones	
M-I, II, III, IV, V	
First phalangeal series	
PP-I, II, III, IV, V	
Second phalangeal series	
SP-II, III, IV, V	
Third phalangeal series	
TP-I, II, III, IV, V	
Joints	
RC.	Radiocarpal
IC.	Intercarpal
CM.	Carpometacarpal
MP.	Metacarpophalangeal
PIP.	Proximal interphalangeal
DIP.	Distal interphalangeal

[1] Professor of Engineering, University of California, Los Angeles; member, Advisory Committee on Artificial Limbs, National Research Council, and of the Technical Committee on Prosthetics, ACAL, NRC.

[2] Instructor in Otolaryngology, College of Medical Evangelists, Los Angeles; formerly Assistant in Engineering Research, University of California, Los Angeles.

The_Anatomy_and_Mechanics_of_the_Human_Hand.pdf(2 MB) - download

2021/10/19-Toward a Physiological Understanding of Human Dexterity

KENZIE HURT - Oct 19, 2021, 10:11 PM CDT

Title: Toward a Physiological Understanding of Human Dexterity

Date: 2021/10/19

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To gain background on the physiology of human dexterity and it's relation to upbringing and mental capabilities.

Search term: google scholar - physiology of grabbing object

Citation: M. Wiesendanger, D. of Neurology, and D. J. Serrien, "Toward a Physiological Understanding of Human Dexterity," Physiology, 01-Oct-2001. [Online]. Available: https://journals.physiology.org/doi/full/10.1152/physiologyonline.2001.16.5.228. [Accessed: 19-Oct-2021].

Link: https://journals.physiology.org/doi/full/10.1152/physiologyonline.2001.16.5.228

Content:

- There are two types of dexterity, which is defined as the skillful manipulation of the hands, that are focused on in the article: grasping and bimanual coordination
- Dexterity depends highly on the powerful distributed neural networks
- During development, sensorimotor memory is created that includes the properties objects, their form, surface texture, weight, color, smell and taste. This is basically saying that while the infant is developing, they are constantly grasping objects with both hands becoming familiar with the parts of objects that pertain to the senses.
- Symmetrical reaching is developed in the first year of life which is the equity in grasping objects effectively with both hands without having to decipher which hand is dominant
- Bimanual coordination developed more slowly in the second year of life and throughout life even. This is often what is thought of as dexterity in which we decipher a dominant hand in which there is better coordination with one rather than the other
- This also plays into the habit and memory of grasping objects using our neural pathways to know how to grab the object
- It has been seen that the non-dominant hand tends to assume a postural role for holding the grasped object which provides a body-centered reference frame whereas the dominant hand has more capabilities to manipulate the object with more specificity.

Conclusions/action items:

Our group should keep this in mind when thinking about the ethics of our prosthetic because the use of the prosthetic should simulate an anatomical hand and be easy to use as if it was actually part of their body. Without the innervation of the prosthetic, dexterity can be more complicated, however there still can be dominant and non-dominant hands and keeping this in mind when fabricating the prosthetic will help with the ethics of this device.

KENZIE HURT - Oct 19, 2021, 10:11 PM CDT

Toward a Physiological Understanding of Human Dexterity

Mario Wiesendanger and Deborah J. Serrien

Dexterity, defined as the skillful manipulation of the hands, is now amenable to physiological investigation. Two topics are discussed here: grasping (i.e., hand-object coupling) and bimanual coordination. Dexterity depends on powerful, distributed neural networks and is particularly vulnerable to brain lesions. A knowledge of physiological mechanisms is needed to deal with these neurological problems.

Toward_a_Physiological_Understanding_of_Human_Dexterity.pdf(650.8 KB) - download

2021/09/14-A new Biomechanical Hand Prosthesis

KENZIE HURT - Sep 14, 2021, 5:41 PM CDT

Title: A New Biomechanical Hand Prosthesis Controlled by Surface Electromyographic Signals

Date: 2021/09/14

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To learn about a competing design that uses signal processing rather than just movement.

Search term: PubMed: hand prosthetic

Citation: N. A. Andrade, G. A. Borges, F. A. de O. Nascimento, A. R. S. Romariz and A. F. da Rocha, "A new biomechanical hand prosthesis controlled by surface electromyographic signals," 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007, pp. 6141-6144, doi: 10.1109/IEMBS.2007.4353751.

Link: https://ieeexplore.ieee.org/document/4353751

Content:

- The individual receiving the prosthetic will have been trained in hand control by electromyographic (EMG) signals
- EMG signals optimize hand control allowing the individual to use the hand with routine tasks
- EMG signals are efficient in controlling and moving the hand certain ways through neuromuscular activation associated with muscular contraction
- Only one degree of freedom
- Utilized myoelectric sensors that were placed strategically choosing the point of largest signal amplitude (reduces effort of individual when activating the signal)
- The prototype was successful in the individual moving the hand through EMG signals with little effort/fatigue of the individual

Conclusions/action items:

Keeping this idea in mind, we will not be using electronics to control the prosthetic, however, this design was similar in the way that the goal was to minimize fatigue while still maximizing strength.

KENZIE HURT - Sep 14, 2021, 5:42 PM CDT

.pdf(1.6 MB) - download

2021/10/11-Underactuated tendon-driven robotic/prosthetic hands: design issues

KENZIE HURT - Oct 11, 2021, 1:02 PM CDT

Title: Underactuated tendon-driven robotic/prosthetic hands: design issues

Date: 2021/10/11

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To learn about a competing design that uses the same tensioning mechanism concept.

Search term: Google - cable hand prosthetic

Citation: Mottard, Annick, Thierry Laliberté, and Clément Gosselin. "Underactuated tendon-driven robotic/prosthetic hands: design issues." *Robotics: Science and Systems*. Vol. 7. 2017.

Link: **Underactuated tendon-driven robotic/prosthetic hands: design issues.**

Content:

- This paper talks about the different issues within the specific design of their prosthetic. It addresses the problems that they were seeing in the different mechanisms that are controlling the movement of the fingers.
- This prosthetic has joints that are joined by a tensioning system rather than what is seen in our design with a pin joint. It is named a rotational sliding joint which allows for extra degrees of freedom within the finger. The rotational sliding joint also allows for the fingers to bend laterally.
- Their design also includes a thumb that is on a pivot joint in which the thumb can be moved in the range of being parallel with the palm to being parallel with the other fingers. They used what is called a cam mechanism in the thumb pivot joint allowing 3 positions of the thumb.

Conclusions/action items:

Keeping this idea in mind, we may be able to implement some of these ideas in our own way to our existing model if we have enough time after implementing the extra phalange nodule.

KENZIE HURT - Oct 11, 2021, 1:03 PM CDT

Underactuated_Prosthetic_Hand.pdf(3.7 MB) - download

2021/10/11-UT hand I: A lock-based underactuated hand prosthesis

KENZIE HURT - Oct 11, 2021, 1:27 PM CDT

Title: UT hand I: A lock-based underactuated hand prosthesis

Date: 2021/10/11

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To learn about a competing design that uses a similar tensioning mechanism concept.

Search term: Science direct - underactuated hand

Citation: B. Peerdeman, M. Valori, D. Brouwer, E. Hekman, S. Misra, and S. Stramigioli, “UT hand I: A lock-based underactuated hand prosthesis,” *Mechanism and Machine Theory.* Vol. 78. 2014. [Online]. Available: https://doi.org/10.1016/j.mechmachtheory.2014.03.018. [Accessed: 11-Oct-2021].

Link: https://www.sciencedirect.com/science/article/pii/S0094114X14001062#bb0030

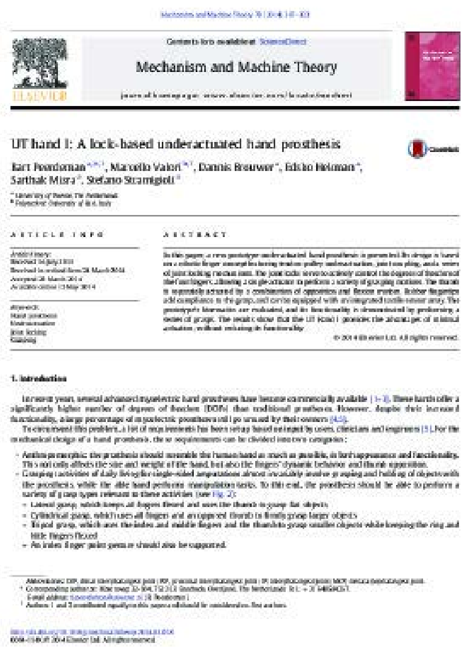
Content:

- This model features tendon-pulley underactuation, joint coupling, and joint locking mechanisms.
- This model utilizes an actuator that controls the different grasping types. The joint locking mechanisms actively control the degrees of freedom for the four fingers with the thumb having a separate mechanism.
- They used four bar coupling in the fingers to help stabilize the velocity of the grasping mechanism such that it grips at a constant speed.
- This model utilized motors and electronics to perform different specific grip types which is different than our prototype.

Conclusions/action items:

The use of a four bar coupling mechanism for the pulley's within the fingers can be useful if we are still having problems with grip strength.

KENZIE HURT - Oct 11, 2021, 1:27 PM CDT



UT_hand.pdf(2.4 MB) - download

2021/12/11-Ethical Considerations for Testing

KENZIE HURT - Dec 11, 2021, 6:33 PM CST

Title: Ethical Considerations for Testing

Date: 12/11/2021

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To discuss ethical considerations of our design.

Search Term: Ethics upper limb prosthetics

Citation: M. Major, “Fall Prevalence and Contributors to the Likelihood of Falling in Persons With Upper Limb Loss” Physical Therapy, vol. 99, pp. 337-387, 2019. [Online]. Available: https://doi.org/10.1093/ptj/pzy156 [Accessed Oct. 19, 2021].

Link: https://academic.oup.com/ptj/article/99/4/377/5252000

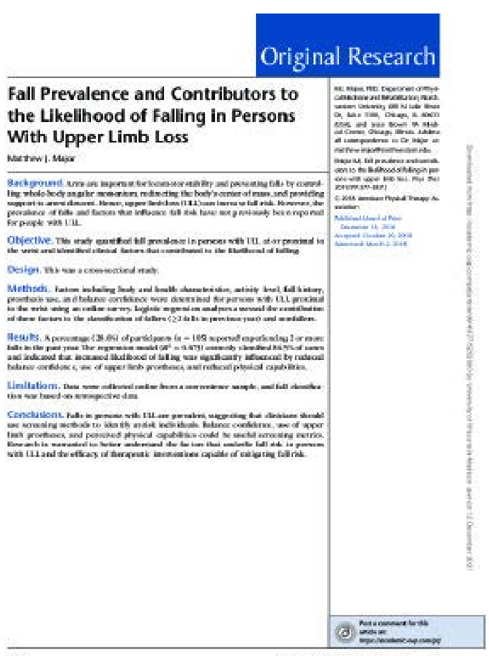
Content:

- Cross sectional studies have shown that there is an increased prevalence of falling with upper limb loss due to “reduced balance confidence, use of upper limb prostheses, and reduced physical capabilities”
- Given that this design idea is adding more weight to the prosthetic, it may affect the user’s center of gravity. This can cause an imbalance while doing daily activities which may lead to more frequent falling.
- In the event that the user does fall, the health and safety of the user as well as the integrity of the prosthetic are at risk if the prosthetic is used to catch the fall. This is another ethical issue that will need to be addressed when conducting research and testing of the device after the design implementation.

Conclusions/action items:

By keeping these ethical considerations in mind when testing and evaluating the phalange extension design, the overall final product will be affordable, safe to use, and effective in grasping objects with a stronger force as opposed to other prosthetics on the market.

KENZIE HURT - Dec 11, 2021, 6:34 PM CST


Original Research

Fall Prevalence and Contributors to the Likelihood of Falling in Persons With Upper Limb Loss

Matthew J. Major

Background.

Objective.

Design. This was a cross-sectional study.

Methods.

Results.

Limitations.

Conclusions.

2019 Volume 99 Number 4 Physical Therapy 377

Fall_Prevalence.pdf(1.4 MB) - download

2021/12/11-Thoughts on Societal Impact

KENZIE HURT - Dec 11, 2021, 6:42 PM CST

Title: Thoughts on Societal Impact

Date: 12/11/2021

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To discuss how the implementation of our design has on the societal impact for users.

Content:

- Upper limb loss affects many different types of people and for different reasons: birth defect, amputation, injury, etc.
- With e_NABLE being a global group of volunteers, they can reach many people around the world and get those in need of prosthetics one that is affordable.
- Since these prosthetics are affordable due to the fact they are just 3D printed, there are some aspects of the prosthetic that are lacking when compared to those on the market.
- By fixing the grip strength of one of the prosthetic models, the idea can then be translated to other models and therefore reach a wider range of people who are using the prosthetic.
- This can greatly lift the burden of the cost of a prosthetic while still keeping aspects of the device that are needed to improve quality of life and tasks of daily living.

Conclusions/action items:

By helping e-NABLE with improving the grip strength of their prosthetics, they are now able to send out stronger, better performing prosthetics while still keeping the cost low. This will have impact globally since e-NABLE is a global non-profit organization.

2021/09/27-Design Ideas

KENZIE HURT - Sep 27, 2021, 10:10 AM CDT

Title: Design Ideas

Date: 09/27/21

Content by: Kenzie Hurt

Present: N/A

Goals: To write down the ideas I've been brainstorming to bring to the meeting.

Content:

1. Move the thumb and have it close on top of fingers when gripping something

2. Have some sort of cable system at top of fingers across all fingers when closing that pushes fingertips down for better/stronger grip

3. Move thumb to make it more like a grabber/claw version where the thumb is more on the palm rather than side of palm

Conclusions/action items:

I will bring these ideas to the meeting tonight and collaborate/combine ideas to come up with our three designs for our design matrix.

2021/10/12-Design Preliminary Drawings

KENZIE HURT - Oct 12, 2021, 9:51 PM CDT

Title: Preliminary Design Drawings for Design Matrix

Date: 10/12/21

Content by: Kenzie Hurt

Present: N/A

Goals: To get our drawings on paper/presentation for our preliminary presentations.

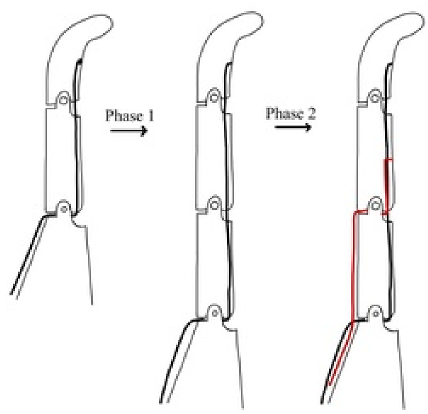
Content:

Drawings included as an attachment below.

Conclusions/action items:

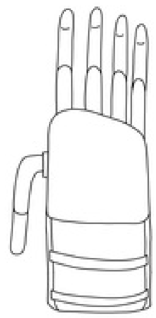
These drawings will be uploaded in our preliminary presentation and also in our design matrix.

KENZIE HURT - Oct 12, 2021, 9:52 PM CDT



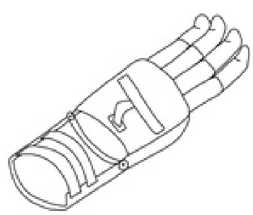
design_1-2.jpg(152 KB) - download Phalange extension/addition

KENZIE HURT - Oct 12, 2021, 9:53 PM CDT



Design_2-3.jpg(99 KB) - download Relocated thumb

KENZIE HURT - Oct 12, 2021, 9:53 PM CDT



Design_3-4.jpg(116.2 KB) - download Bar thumb

2021/11/01-Possible Testing

KENZIE HURT - Nov 01, 2021, 5:19 PM CDT

Title: Possible Testing

Date: 11/01/2021

Content by: Kenzie Hurt

Present: Kenzie Hurt

Goals: To talk with Professor Henak about possible testing protocols.

Content:

- first look into the ways that doctors measure grip strength (like for patients just having surgery on their hands)

- look into torsional springs and use spring constant for the normal force to the center and the phase angle

- look into linear springs and use the spring constant and displacement to find the normal force

Conclusions/action items:

Looking into how doctors test grip strength, we are going to look into hand held dynamometers as this should test the normal force to the center of the object being grasped. I will be asking another one of my professors of where we may be able to obtain one.

2021/12/03-Testing Data

KENZIE HURT - Dec 03, 2021, 1:26 PM CST

Title: Testing Data

Date: 12/03/21

Content by: Kenzie Hurt

Present: N/A

Goals: To provide the data in Matlab and the graphs we got from our dynamometer testing

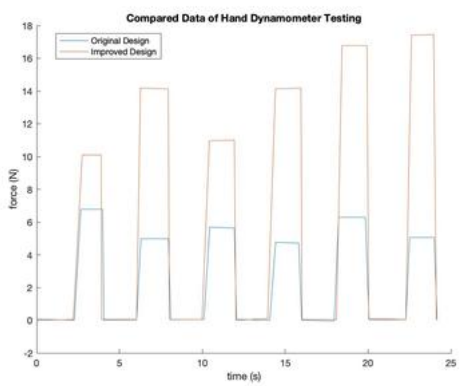
Content:

- I used some digitizing software called Engauge digitizer to get our data into a .csv file in order to do data analysis on it
- I then loaded the digitized data into Matlab and created graphs from it

Conclusions/action items:

My next steps are going to be doing statistical analysis on the data that I got loaded in Matlab, however we will be discussing as a team what kind of data analysis we will be doing that would be sufficient in getting what we need out of the data.

KENZIE HURT - Dec 03, 2021, 1:40 PM CST



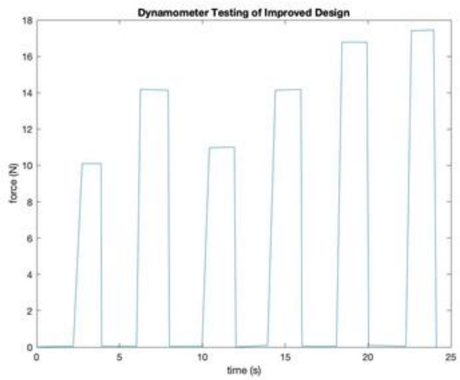
Compared.jpg(49.3 KB) - download

KENZIE HURT - Dec 03, 2021, 1:40 PM CST

```
%% Dynamometer Testing of Improved Design
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Improved.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
data = importdata([path,filesep,file]);
time = data.data(:,1);
kg_force = data.data(:,2);
force = kg_force*9.81;

figure(1);
plot(time, force);
title('Dynamometer Testing of Improved Design');
xlabel('time (s)');
ylabel('force (N)');

%% Dynamometer Testing of Original Design
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Original.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
data = importdata([path,filesep,file]);
time = data.data(:,1);
kg_force = data.data(:,2);
force = kg_force*9.81;

figure(1);
plot(time, force);
title('Dynamometer Testing of Original Design');
xlabel('time (s)');
ylabel('force (N)');

%% Comparison
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Original.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
original = importdata([path,filesep,file]);
o_time = original.data(:,1);
o_kg_force = original.data(:,2);
o_force = o_kg_force*9.81;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Improved.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
improved = importdata([path,filesep,file]);
i_time = improved.data(:,1);
i_kg_force = improved.data(:,2);
i_force = i_kg_force*9.81;

figure(1);
hold on;
title('Compared Data of Hand Dynamometer Testing');
plot(o_time, o_force);
plot(i_time, i_force);
xlabel('time (s)');
ylabel('force (N)');
```

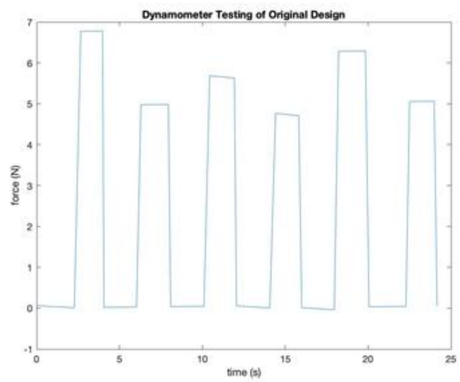
dynamometer_testing.m(1.6 KB) - download

KENZIE HURT - Dec 03, 2021, 1:28 PM CST



Improved.jpg(46 KB) - download

KENZIE HURT - Dec 03, 2021, 1:28 PM CST



Original.jpg(44.7 KB) - download

KENZIE HURT - Dec 06, 2021, 3:33 PM CST

Title: Testing Data

Date: 12/06/21

Content by: Kenzie Hurt

Present: N/A

Goals: To show the analysis of our data and prove that it has statistical significance difference.

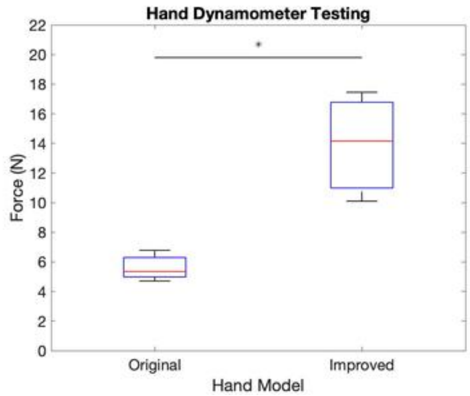
Content:

- After loading the data into MatLab, I ran a t-test to prove that the improved design of our hand had a significant difference when compared to the original hand.
- To prove significant difference, the p value must be less than 0.05 and our p value was 1.49e-09. This proves that our design is significantly different than the original design, therefore showing that c

Conclusions/action items:

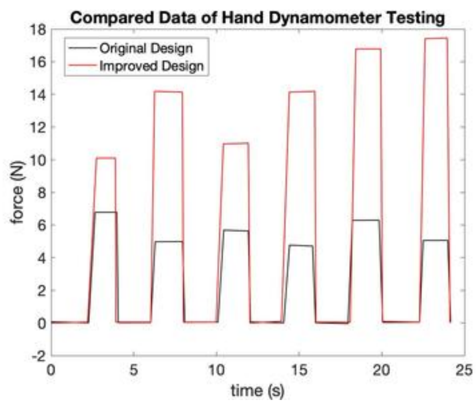
This concludes the data analysis of our quantitative testing with the dynamometer. After running the t-test, it was proven that our improved design did significantly improve the grip strength of the prosthetic as compared to the original design.

KENZIE HURT - Dec 06, 2021, 3:35 PM CST



boxplot.jpg(43.2 KB) - download

KENZIE HURT - Dec 06, 2021, 3:35 PM CST



Compared.jpg(68.9 KB) - download

KENZIE HURT - Dec 06, 2021, 3:35 PM CST

```
%% Dynamometer Testing of Improved Design
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Improved.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
data = importdata([path,filesep,file]);
time = data.data(:,1);
kg_force = data.data(:,2);
force = kg_force*9.81;

figure(1);
plot(time, force);
title('Dynamometer Testing of Improved Design');
xlabel('time (s)');
ylabel('force (N)');

%% Dynamometer Testing of Original Design
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Original.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
data = importdata([path,filesep,file]);
time = data.data(:,1);
kg_force = data.data(:,2);
force = kg_force*9.81;

figure(1);
plot(time, force);
title('Dynamometer Testing of Original Design');
xlabel('time (s)');
ylabel('force (N)');

%% Comparison
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Original.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
original = importdata([path,filesep,file]);
o_time = original.data(:,1);
o_kg_force = original.data(:,2);
o_force = o_kg_force*9.81;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Improved.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
improved = importdata([path,filesep,file]);
i_time = improved.data(:,1);
i_kg_force = improved.data(:,2);
i_force = i_kg_force*9.81;

figure(1);
p = plot(o_time, o_force, 'k', i_time, i_force, 'r');
p(1).LineWidth = 1;
p(2).LineWidth = 1;
ax = gca;
ax.FontSize = 16;
title('Compared Data of Hand Dynamometer Testing');
```

dynamometer_testing.m(2.3 KB) - download

2021/09/17 Medical Applications of 3D Printing

Max WIELAND - Sep 17, 2021, 9:16 AM CDT

Title: Medical Applications of 3D Printing

Date: 09/17/2021

Content by: Max Wieland

Present:

Goals: Understand how 3D printing is implemented into medical devices and why

Citations: Durfee, William K, and Paul A Laizzo. “Medical Applications of 3D Printing.” Medical Applications of 3D Printing - ScienceDirect, Academic Press, 16 Nov. 2018,

[Chapter Link]

Content:

WHY 3D PRINT?

3D printing has the uniqueness of being able to form and create models and objects that have arbitrary complexity compared to traditional ways of manufacturing. 3D printing also allows for models to be duplicated and remade in relatively fast times. In the realm of 3D printing, there are many types of technology that come with it and are available.

TYPES OF PRINTING

FFF is more common since it usually used low cost materials and prints as one continuous layer of the heated filament.

SLA uses a liquid resin and has the ability to create objects from the bottom up or from top down.

For polymers such as nylon or polyamide, an SLS is used to laser the powdered material to form a solid without the need of liquification. One bonus of SLS is that is prints in such a way that you don't need to have supports since the structure is surrounded by unbound power all the time.

DMLS and EBM are ways to print metals such as cobalt, aluminum, titanium, etc... DMLS uses the same system as SLS and EBM uses a electron beam onto powdered metal to form the structure in a vacuum environment.

PROSTHETICS

3D printing can help those with needs that are usually met with payments that can easy make it into the hundreds and thousands of dollars. With3D printing, people can have a low-cost alternative option compared to many of the high end tech out there for things such as prosthetic appendages. E-NABLE is an organization that is a collaborative effort of people around the world to print and send low-cost prosthetics hands to those who would benefit from it, including younger children. With PLA being able to be multicolored, and have unique designs, the E-NABLE hands are quite unique in the way that they can customize the hands for kids.

OTHER

Another application of 3D printing that has been become more prevalent is the printing of implants. For example, The University of Michigan research team created an implant for a 5-month infant who was presented with tracheo-bronchomalacia, in which the bronchus blocks airflow due to its collapse. They designed a splint from polycaprolactone and was successfully placed into the 5-month infant.

Conclusions/action items:

The basis of 3D printing for medical use has been around for a decent amount of time now and is still growing and adapting every minute. We can use it to better understand the body and create models when needed. With the low-cost methods, now a days, medical devices can be made to support communities with affordable prosthetics using simple PLA.

Max WIELAND - Sep 17, 2021, 9:17 AM CDT

CHAPTER 21

Medical Applications of 3D Printing

William K. Durfee[1] and Paul A. Iaizzo[2]
[1]Department of Mechanical Engineering, University of Minnesota, Minneapolis, MN, United States
[2]Department of Surgery, Institute for Engineering in Medicine, University of Minnesota, Minneapolis, MN, United States

21.1 INTRODUCTION

3D printing is defined as an additive manufacturing method that can build objects directly from a computational model. Unlike traditional manufacturing methods such as milling and molding, 3D printing can construct models of arbitrary complexity in relatively fast time frames. Typically, computer models can be an original design or they can be derived from scanned objects that exist or even processed from medical images.

3D printing is a powerful tool for visualizing complex human or animal anatomies and can be used for surgical planning, physician and patient education, medical procedure training, medical device prototyping, and personalized medical device manufacturing. 3D printing technology is rapidly evolving with advances in materials, resolution, and speed thus enabling greater realism and higher accuracy; this in turn enables new medical applications. To meet such needs at the University of Minnesota (Minneapolis, MN, USA), the Institute for Engineering in Medicine developed a *3D Modeling and Printing Core* to serve associated members; this core is currently under the direction of Professor William Durfee.

The pace of development within 3D printing technologies moves so rapidly that, by the time you read this chapter, nearly all current technologies will be out of date. For example, one recent review on the 3D printing industry noted over 250 articles reporting on clinical trials where 3D printing has played a role.[1] Therefore, the objective of this chapter is not to review the latest 3D printing medical applications technology, but rather to provide the reader with a background in what 3D printing could do for you, a brief description of how the majority of current 3D printers work, and how printing has been (and could be) used in various medical applications. For additional information, the reader can consult recent reviews.[1–15]

21.1.1 A brief history of 3D printing

The modern era of 3D printing is generally considered to have started in 1984, when Hull[16] filed his patent for stereolithography and later cofounded 3D Systems, the start of commercial 3D printing. Hull also invented the STL file format that is now

Engineering in Medicine
DOI: [illegible]

3D_Printing_in_Medical_Field.pdf(2 MB) - download

2021/10/19 Human Hand Anatomy-Based Prosthetic Hand

Max WIELAND - Oct 19, 2021, 10:49 PM CDT

Title: Human Hand Anatomy-Based Prosthetic Hand

Date: 10/19/2021

Content by: Max Wieland

Present: n/a

Goals: Look into different types of hand characteristics

Citations: : Dunai, L.; Novak, M.; García Espert, C. Human Hand Anatomy-Based Prosthetic Hand. Sensors 2021, 21, 137. https://dx.doi.org/10.3390/s21010137

Content:

Methods of Prototyping:

Technology now a days can be used to 3D scan real human hand phalanges and then design prosthetic hand structures for the design and assembly. PLA is the most common filament due to the good functional and structural characteristics that are suitable for most 3D prints for prosthetics.

Joints and parts of the human/prosthetic hand:

The prosthetic hand kinematics is based upon the anatomically sound hand anatomy. There is the volar plate, collateral ligaments, and extensor ligaments. They use rubber materials with different hardness for different elements of the finger. The abduction/adduction movement of the phalanges is finite to the point in most prosthetics they are not incorporated into the design. The only true existing abduction/adduction and flexion/extension movement that is incorporated into prosthetic designs is between the metacarpal bone and the proximal phalange.

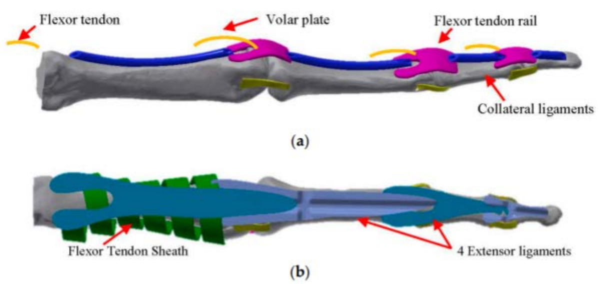


Figure 3. **(a)** Finger flexor tendon route and joins (two side collateral ligaments and volar plate). **(b)** Finger extensor tendons. Three-dimensional model of the prosthetic index finger assembly.

Electronic systems in prosthetics:

The hand control mostly has five force sensing resistors. They are places at the distal phalange muscle and are build/designed with a soft flex material. The artificial muscle is fabricated with rubber and enables the join to perform 3DOF motion (flexion, extensions, abduction, adduction, and rotational motions)

The thumb's usual angle of the thumb can abduct to 80 degrees, the motion of the other fingers are 0-90 degrees. The actuators and EMG are placed in the prosthesis forearm, while the servomotor for the abduction/adduction movement of the thumb is located in the carpal bones of the prosthesis. The electronic system is based on EMG sensors, servo motors, Arduino AtMega 2560, pushbuttons, and a sensor register.

Conclusions/action items:

There are many ways to control the hand movement for prosthetics using mechanics and there are also many ways that parts can be 3D printed and fabricated. Using PLA as the main resource, we can expect a good foundational and structurally sound design. Then using supplementary soft flexible materials, manufactures are able to make good tendons and good ligaments that are similar to the anatomy of a hand.

Max WIELAND - Oct 19, 2021, 10:50 PM CDT

Human_Hand_Anatomy-Based_Prosthetic_Hand.pdf(4.3 MB) - download

2021/09/19 Hero Arm (Open Bionics)

Max WIELAND - Sep 25, 2021, 11:03 AM CDT

Title: Hero Arm (Open Bionics)

Date: 09/19/2021

Content by: Max Wieland

Present:

Goals: Know what characteristics the competing designs have

Citations: "Meet the Hero Arm -a prosthetic arm for adults and children." Open Bionics, 2021, https://openbionics.com/hero-arm/.

Link

Content:

WHAT IS IT:

The Hero Arm is a lightweight, multi-grip prosthetic arm that uses 3D printed models to form and design a "perfect" fitting prosthetic manufactured with Nylon 12. Since it is created with lightweight materials, it is one of the most affordable bionic arms on the market right now.

HOW IS IT A COMPETITOR:

Being one of the more affordable options for prosthetic hands/arms on the market, eNABLE's 3D printed hands may have competition if the Hero Arm has superior qualities, which will be described in the details section of this report.

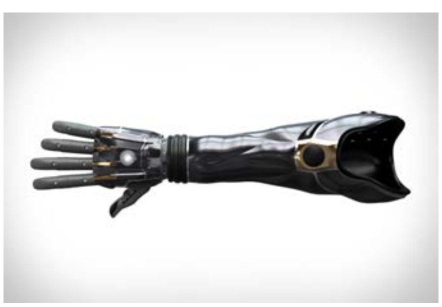
DESIGN DETAILS:

Materials: it is a myoelectric prosthesis and is made with Nylon 12 materials.

Design: It is designed to the client's needs and specifications. They design around a 3D scan of the client's limb, then create the full prosthesis (highlighting the innovative adjustable and breathable socket for ease of fitting and taking on/off)

Tech: They have specialized sensors that detect muscle movement and reads them to produce intuitive life-like precise movements. As well, they have vibrators, beepers, buttons, and lights to indicate specific movements of the arm.

Grip and Lifting: although one of the most lightweight arms on the market, it can lift up to 17.64 lbs and has 6 grip types to select. With multi-grip versatility, it can send feedback to the client while they are controlling it. It also has a freeze mode, which allows the arm to be held in a static position, for a better, more reliable grip. Along with the grip types and freezing modes, the control on the arm is proportional, thus allowing for different finger speeds, as well as posable thumbs and a wrist rotation of 180 degrees.



citation

Conclusions/action items:

Although these arms are not 3D printed and sourced through a non-profit like eNABLE, the Hero Arm has potential and design quirks that are far superior than any eNABLE hand. Granted, it is mechanically powered, but for it being on the cheaper side of the bionic arm/hand market, we can look at this to see how we can better the eNABLE hand to improve it.

2021/10/18 3D Printing materials

Max WIELAND - Oct 18, 2021, 5:55 PM CDT

Title: Exploring Exotic 3D Printing Materials

Date: 10/18/2021

Content by: Max Wieland

Goals: Learn about materials used in 3D printed prosthetics

Source: S. McCulloch, “Exploring exotic 3D printing materials used in prosthetics,” *Shapeways Blog*, 20-Dec-2019. [Online]. Available: https://www.shapeways.com/blog/archives/40103-exploring-exotic-3d-printing-materials-used-prosthetics.html. [Accessed: 18-Oct-2021].

Content:

PLA is one of the most reliable, inexpensive and easy to print with, making it a material that can be used for a wide range of things.

CFR (Carbon Fiber Reinforced Filament): is commonly used for the socket part of prosthetic legs. Due to its properties of having carbon strands in a plastic, it can be created and then re-melted.

TPU (Flexible Filament): thermoplastic polyurethane is a soft and flexible material is good for making mesh-like joints and such in prosthetics. In bionic hands, flexible filament is used since it gives a more natural motion to the flanges. Compared to the rigid mechanism that other filament results in, TPU greatly shortens the assembly time and the manufacturing process.

ETPU (Conductive Filament): This filament is used mostly to conduct sensors. Since we are not using sensors, we do not need to specifically focus on this. However, ETPU is used in bionic prototypes as it can be an effective 3D filament for touch sensors and when creating pressure simulation for prosthetic fingertips.

Conclusions/action items: PLA is the most common and most available filament thus it is the more commonly used for 3D printing prosthetics. There are more expensive and less readily available filaments that could be used and are used commercially.

Max WIELAND - Oct 18, 2021, 5:54 PM CDT


Shapeways Blog

3D PRINTING NEWS AND INNOVATION

Exploring Exotic 3D Printing Materials Used in Prosthetics

Carbon Fiber Reinforced Filament

Exploring_Exotic_3D.pdf(1.7 MB) - download

2021/09/25 Design Idea I

Max WIELAND - Sep 25, 2021, 11:17 AM CDT

Title: Bar Stopper Idea

Date: 09/25/2021

Content by: Max Wieland

Present: Max Wieland

Goals: Have a few design ideas by the 27th to present to the group

Content: Attached image below

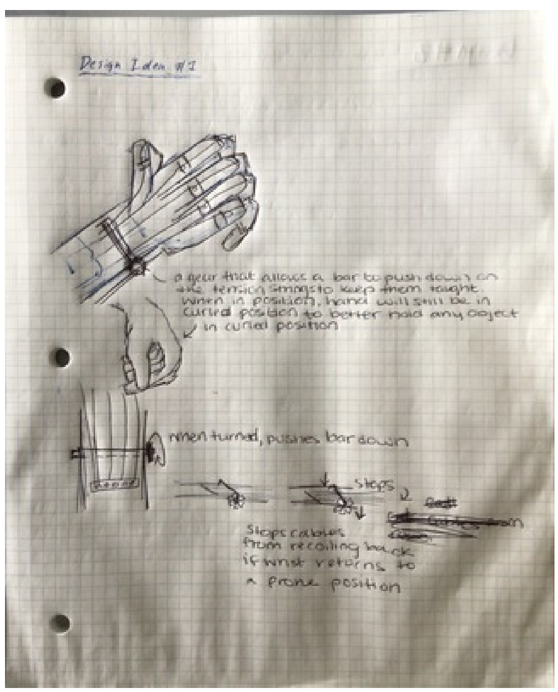
Text on image is as follows:

A gear that allows a bar to push down on the tension strings to keep them taught. When in position, hand will still be in curled position to better hold any object in curled position.

When turned, pushes bar down. Stops. Stops cables from recoiling back if wrist returns to a prone position.

Conclusions/action items: Keep brainstorming rough sketch ideas for ideas on improving grip strength

Max WIELAND - Sep 25, 2021, 11:08 AM CDT



Design1.png(851.5 KB) - download

2021/09/25 Design Idea II

Max WIELAND - Sep 25, 2021, 11:37 AM CDT

Title: Adjustable Thumb Flexion

Date: 09/25/2021

Content by: Max Wieland

Present: Max Wieland

Goals: Have a few design ideas by the 27th to present to the group

Content: Attached image below

Text on image is as follows:

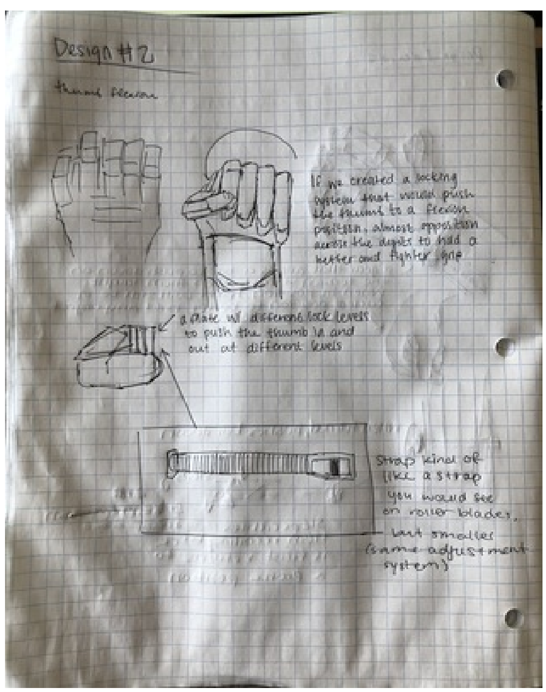
If we created a locking system that would push the thumb to a position (flexion) almost as close a opposition across the digits to hold a better and tighter grip.

A plate w/ different lock levels to push the thumb in and out at different levels.

Strap kid of like a strap you would see on roller blades, but smaller. (Same adjustment system)

Conclusions/action items: Keep brainstorming rough sketch ideas for ideas on improving grip strength

Max WIELAND - Sep 25, 2021, 11:37 AM CDT



Design2.png(2.2 MB) - download

2021/10/12 Solidworks Model Design

Max WIELAND - Dec 06, 2021, 5:38 PM CST

Title: SolidWorks files and model pictures

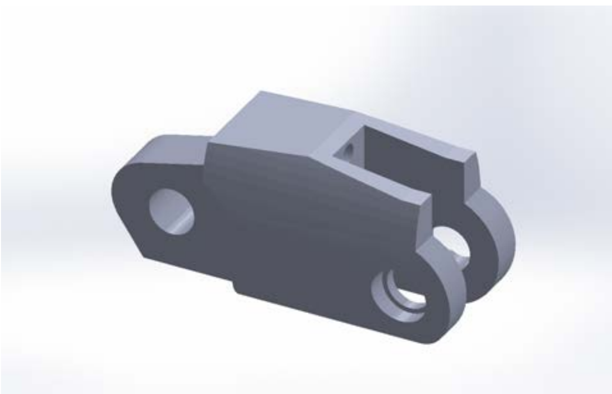
Date: October 12th, 2021

Content by: Max Wieland (Model by Sam Strachan, Images by Matthew Wroblewski)

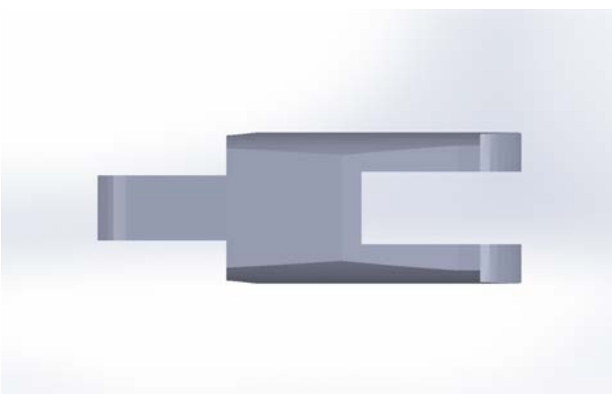
Present:

Goals: To have the files for the phalange extensions uploaded and ready to print

Content:



3D View of a single extension piece



3D View of the top of a single extension piece

3D View of the side of a single extension piece

3D View of the front of a single extension piece

Conclusions/action items:

Once everything is finalized we will then request a printout of the design to get an idea of what we need to fix or redesign, then further design and print a finalized version for the hand.

Max WIELAND - Dec 04, 2021, 3:49 PM CST

Phalange.STL(75.6 KB) - download

2021/12/03 Testing Data Documentation

Max WIELAND - Dec 06, 2021, 6:38 PM CST

Title: Testing Data

Date: 12/03/21

Content by: Kenzie Hurt, documented by Max Wieland for notebook purposes

Present: N/A

Goals: To provide the data in Matlab and the graphs we got from our dynamometer testing

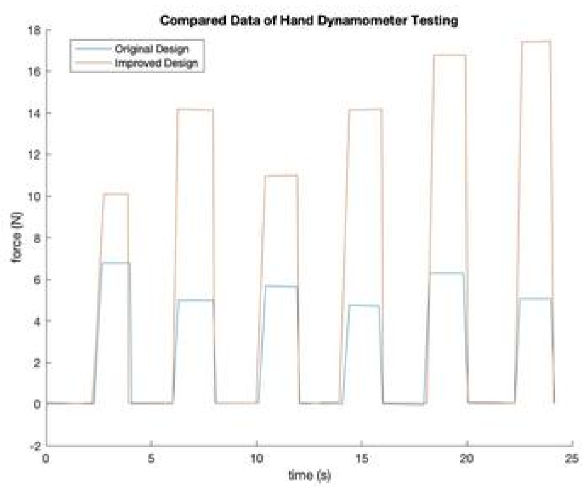
Content:

- Kenzie was able to utilize a software called Engauge digitizer to get data turned unto a .csv file to be able to analyze it properly.
- Kenzie was able to put the .csv file into Matlab and further analyze with graphical data

Conclusions/action items:

Our next step as a team will be using this data to do statistical analysis for accurate numbers and our finalized quantitative data

Max WIELAND - Dec 06, 2021, 6:31 PM CST

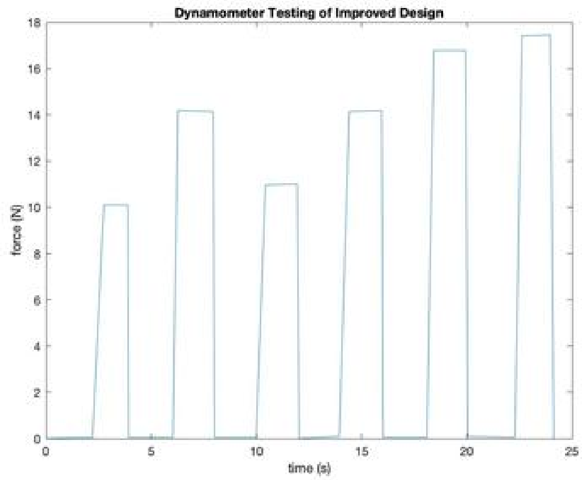


Compared.jpg(49.3 KB) - download

Max WIELAND - Dec 06, 2021, 6:31 PM CST

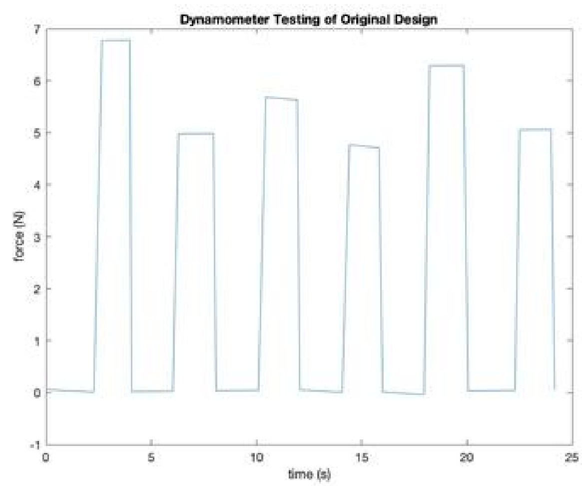
dynamometer_testing.m(1.6 KB) - download

Max WIELAND - Dec 06, 2021, 6:31 PM CST



Improved.jpg(46 KB) - download

Max WIELAND - Dec 06, 2021, 6:31 PM CST



Original.jpg(44.7 KB) - download

Max WIELAND - Dec 06, 2021, 6:38 PM CST

Title: Testing Data

Date: 12/06/21

Content by: Kenzie Hurt, documented by Max Wieland for notebook purposes

Present: N/A

Goals: To show the analysis of our data and prove that it has statistical significance difference.

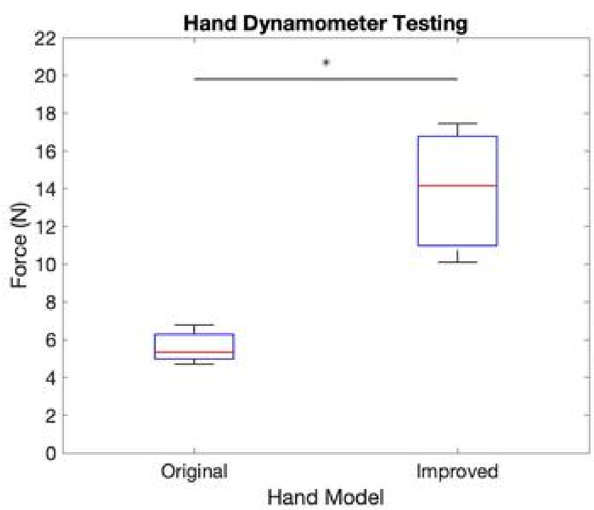
Content:

- Kenzie was able to upload and run a t-test for the data that she previously collected. The t-test proved that the improved design of the hand was significantly better than the original.
- To prove significant difference, the p value must be less than 0.05 and our p value was 1.49e-09. This proves that our design is significantly different than the original design, therefore showing that our improved design did improve the grip strength.

Conclusions/action items:

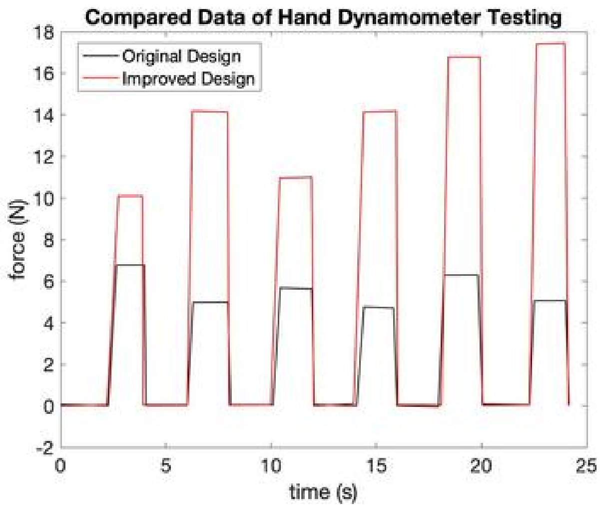
This concludes the data analysis of our quantitative testing with the dynamometer. After running the t-test, it was proven that our improved design did significantly improve the grip strength of the prosthetic as compared to the original design.

Max WIELAND - Dec 06, 2021, 6:31 PM CST



boxplot.jpg(43.2 KB) - download

Max WIELAND - Dec 06, 2021, 6:31 PM CST



Compared.jpg(68.9 KB) - download

Max WIELAND - Dec 06, 2021, 6:31 PM CST

```
%% Dynamometer Testing of Improved Design
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Improved.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
data = importdata([path,filesep,file]);
time = data.data(:,1);
kg_force = data.data(:,2);
force = kg_force*9.81;

figure(1);
plot(time, force);
title('Dynamometer Testing of Improved Design');
xlabel('time (s)');
ylabel('force (N)');

%% Dynamometer Testing of Original Design
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Original.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
data = importdata([path,filesep,file]);
time = data.data(:,1);
kg_force = data.data(:,2);
force = kg_force*9.81;

figure(1);
plot(time, force);
title('Dynamometer Testing of Original Design');
xlabel('time (s)');
ylabel('force (N)');

%% Comparison
close all;
clear all;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Original.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
original = importdata([path,filesep,file]);
o_time = original.data(:,1);
o_kg_force = original.data(:,2);
o_force = o_kg_force*9.81;

[file, path] =
uigetfile('/Users/kenziehurt/Documents/MATLAB/BME300/Improved.csv','/Users/
kenziehurt/Documents/MATLAB/BME300');
improved = importdata([path,filesep,file]);
i_time = improved.data(:,1);
i_kg_force = improved.data(:,2);
i_force = i_kg_force*9.81;

figure(1);
p = plot(o_time, o_force, 'k', i_time, i_force, 'r');
p(1).LineWidth = 1;
p(2).LineWidth = 1;
ax = gca;
ax.FontSize = 16;
title('Compared Data of Hand Dynamometer Testing');
```

dynamometer_testing.m(2.3 KB) - download

9/20/21 Grip Force Control

SHREYA SREEDHAR - Sep 21, 2021, 11:35 AM CDT

Title: Grip Force Control

Date: 9/20/21

Content by: Shreya S.

Present: N/A

Goals: Look at previous designs and research done on prosthetic grip strength. Understand how to make the Pheonix Reborn hand design better.

Content:

- Upper-limb prosthesis users are not able to take advantage of sensory cures to modulate force when manipulating an object, at least at the level of the hand.

- The voluntary opening (VO) device is naturally closed and requires an increase of cable tension to open.

- The voluntary closing (VC) device is naturally open and requires an increase of cable tension to close.

- The results of the study indicated that the VC device allowed task completion to be 1.3 sec faster on average than the VO.

Conclusions/action items:

- VC device would be a more efficient prosthetic.

- look into hand prosthetics specifically, since this one was mostly for upper limb prosthetics.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6190905/

9/20/21 Performance Characteristics of Anthropomorphic Prosthetic Hands

SHREYA SREEDHAR - Sep 21, 2021, 11:40 AM CDT

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

Screen_Shot_2021-09-21_at_11.40.09_AM.png(144.3 KB) - download

SHREYA SREEDHAR - Sep 21, 2021, 11:44 AM CDT

Title: Performance Characteristics of Anthropomorphic Prosthetic Hands

Date: 9/20/21

Content by: Shreya

Present: N/A

Goals: To learn more about the mechanisms of hand prosthetics.

Content:

- The human hand has an average weight of 400 grams

- A recent internet survey of myoelectric prosthetic users concluded that 79% considered that their device was “too heavy”.

- The prosthetic hand structure should have a length between 180-198 mm and a width of 75- 90 mm to match normal human hand size

- The average myoelectric prosthetic hand user will wear their device in excess of 8 hours per day

- The thumb accounts for up to 40% of the entire functionality of the human hand [34] and therefore the design of the thumb in any anthropomorphic prosthetic hand is extremely important

Conclusions/action items:

This article provided meaningful insight for PDS details. The thumb is a key part of the hand and our group should aim for higher than 40% functionality of our prosthetic.

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

10/18/21 Victoria Hand Project

SHREYA SREEDHAR - Oct 18, 2021, 9:56 PM CDT

Title: Victoria Hand Project

Date: 10/05/21

Content by: Shreya Sreedhar

Present: Shreya Sreedhar

Goals: To learn more about competing designs on the market.

Content:

The Victoria hand project aims to provide inexpensive, anatomically sound prosthetic hands to not only help with faily functions, but also help user feel more integrated in society.

- Price is approximately 100$

- The thumb can be rotated (adduct/abduct) by the user, to achieve different positions allowing for many different grasps. This includes a one-finger pinch, a two-finger pinch, a power grasp, or a lateral grasp.

- The voluntary close (VC) model contains the back-lock mechanism. This lets the user lock the hand closed, for tasks such as carrying bags, or constant grip onto objects.

- The wrist contains a ball-and-socket mechanism that allows the user to quickly and easily change the orientation of the hand. This wrist can rotate the hand up to 360 degrees, while simultaneously being flexed or extended by 25 degrees.

- The Adaptive Grasp mechanism allows the fingers to conform around the shape of oddly shaped objects making them easier to grasp and hold.

Conclusions/action items:

This Victoria hand design aligns very well with our goals for this design. The one pitfall is the locking design. Our client specifically mentioned that he wanted us to stay away from the locking mechanism.

To do-

-Consider integrating a ball and socket at the joint between the hand and forearm

-Consider making the thumb able to rotate.

https://www.victoriahandproject.com/vhp-hands

10/20/21 Hero arm

SHREYA SREEDHAR - Oct 20, 2021, 8:57 AM CDT

Title: Hero Arm competing design

Date: 10/20/21

Content by: Shreya

Present: Shreya

Goals: To better understand competing products on the market

Content:

- **They** take a 3D scan of your limb, use clever software and design to manufacture your Hero Arm using tough Nylon 12.

-Claims that this product is affordable but does not specify how much.

- Sensors within the Hero Arm detect muscle movements, meaning you can effortlessly control your bionic hand with intuitive life-like precision. Also, haptic vibrations, beepers, buttons and lights provide you with intuitive notifications to help you control bionic arm movements.

-This is a passive bionic arm. User does not have to actively move/lock the arm

https://openbionics.com/hero-arm/

Conclusions/action items:

- Think about the idea of taking a 3d scan of someone's hand/arm to provide the best fit for the user.

-Consider using Nylon 12 and do more research on that material to see if it is feasible for us to use.

10/18/21 Material for 3D printing

SHREYA SREEDHAR - Oct 18, 2021, 10:11 PM CDT

Title: Materials for 3D printing prosthetics

Date: 10/18/21

Content by: Shreya

Present: Shreya

Goals: Learn about the best material to print prosthetics with.

Content:

https://www.bbc.com/news/technology-16907104

- In this story a woman received a 3D printed bone implant.

-It used a laser beam to melt successive thin layers of titanium powder together to build the part.

-The titanium powder was good method to replicate bone

Conclusions/action items:

-Although this is a revolutionary way to 3D print for biomedical reasons, it is beyond the scope of this class for us to use a material like titanium powder.

10/20/21 - Nylon 12 filament

SHREYA SREEDHAR - Oct 20, 2021, 9:03 AM CDT

Title: Nylong 12 filament

Date: 10/20/21

Content by: Shreya

Present: Sreedhar

Goals: Understand if nylon 12 is a feasible material to print with in our project.

Content:

-The strength, toughness and excellent fatigue properties of FDM Nylon 12 make it a perfect fit for applications involving snap-fit closures, tools with press-fit inserts and vibration-resistant parts.

- Is mostly used in low-volume production and highly customized parts.

- It is affordable to use.

- It is tough and can ensure tensile stress. It can bend and flex without damage to the material.

Conclusions/action items:

- Do some research on the Makerspace and if it is compatible with the Makerspace printers.

- Determine if our material needs to have "flex" to it or can it just be rigid.

11/3/21 Makerspace printing options

SHREYA SREEDHAR - Dec 14, 2021, 2:35 PM CST

Title: Makerspace printing options

Date: 11/3/21

Content by: Shreya

Present: Shreya

Goals: To better understand what 3D printing options the UW Makerspace has and what option would be the most useful for our project.

Content:

Types of printers available for use:

-Ultimaker (FFF)

-Formlabs Form 2 and 3s (SLA)

-Formlabs fuse 1 (SLS)

-Stratasys F370 (FFF)

-For our project the most useful printers will most likely be the Ultimaker and the Formlabs Form 2 and 3s due to the material it uses to print and the cost of the printing process. Since one of our main goals in this project is to keep the fabrication process cost effective it is a big factor when it comes to choosing material/printer.

-If using the Ultimaker we will most likely use PLA. PLA is very cheap to use however it can cause rigid edges in the final print because we will need to remove the support around the print and file it down. This can be time consuming as well.

-If using the Formlabs Form 2 and 3s we will be using a dip resin to produce our part. This will provide a very smooth and sleek print without too much postprocessing work on our ed, however it is more expensive to print than PLA.

Conclusions/action items:

-Discuss with group which printing method makes more sense with our project. We will need to make a decision on price and quality of the product.

https://making.engr.wisc.edu/3d-printers-2/

Possible testing ideas 11/12/21

SHREYA SREEDHAR - Nov 12, 2021, 12:30 PM CST

Title: Possible testing idea

Date: 11/12/21

Content by: Shreya

Present: Shreya

Goals: To get ideas for testing protocol that we can follow for our original hand and our design edition.

Content:

-We can use some type of strip sensor to test the amount of force that the hand applies to different types of objects.

-The sensor can be attached to the flat part of the finger on the hand or the object itself.

-It may be more useful to put the sensor on the object, because the point of contact between the object and the hand may differ for each object.

-Tekscan has pressure mapping sensors for force measurements.

-This sensors would give us the normal force on the object which is equal to force exerted by the hand.

Con- expensive. This sensor is 114$ https://www.tekscan.com/products-solutions/force-sensors/a502

Conclusions/action items:

-Discuss with team if this is a feasible testing option.

-Continue research on other testing options

Statistical analysis for quantitative testing 11/19/21

SHREYA SREEDHAR - Dec 11, 2021, 4:13 PM CST

Title: Statistical analysis test for testing data

Date: 11/19/21

Content by: Shreya Sreedhar

Present: Shreya Sreedhar

Goals: Determine which statistical analysis test is the best to use to prove statistical significance of our data.

Content:

-Some examples of statistical tests: t-test, z-test, ANOVA, two sided t test etc.

-In our data we want to validate or invalidate the equivalence between two samples. One sample will be the data with the original hand and the second sample of data wil come from the modified hand design. Due to this, we will need a two sided t test.

- So we will have two samples, a theoretical difference between the means as well as a range within which we can say that the sample means are equivalent. This is under the assumption that the samples are normally distributed.

-This type of t test can be done in Rstudio.

-Code for RStudio:

```
B = c(x,y,z...)

A = c( x,y,z...)

D = B - A

t.test(D, alternative="greater")
```

-The null hypothesis would mean that the difference in means is 0 meaning the data are equivalent. If the p value is less that .05, then we reject the null hypothesis and reach the conclusion that the data are not equivalent.

-In our case, we want our data to reject the null and prove that the modified hand data values are not equivalent to the original hand values.

Conclusions/action items:

-Use the code I produced above to get a p-value to determine if the data is proving that the modified hand does have a stronger grip strength than the original.

References:

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3019319/

https://www.rdocumentation.org/packages/equivalence/versions/0.7.2/topics/tost

Statistical analysis testing for qualitative testing 11/20/21

SHREYA SREEDHAR - Dec 11, 2021, 4:33 PM CST

Title: Statistical analysis testing for qualitative testing

Date: 11/20/21

Content by: Shreya

Present: Shreya

Goals: To understand different statical tests to prove that the qualitative data is statistically significant.

Content:

-For qualitative testing the data is either success or failure. Since it is yes/no data instead of numerical data we can do a proportion test.

-A proportion test has to satisfy the success/failure condition: i*f we have 5 or more successes in a binomial experiment ($n*p \geq 10$)* and *5 or more failures ($n*q \geq 10$), then you can use a normal distribution to approximate a binomial.*

-We plan to do qualitative testing using a red bull can, arizona tea and hydroflask. We would need to test each item enough times to get 5 or more failures/successes with each hand.

-Once we get that data, we can use the following R studio code to determine statical significance:

```
prop.test(x, n, p = NULL,
          alternative = c("two.sided", "less", "greater"),
          conf.level = 0.95, correct = TRUE)
```

-`prop.test` can be used for testing the null that the proportions (probabilities of success) in several groups are the same, or that they equal certain given values.

References:

https://www.rdocumentation.org/packages/stats/versions/3.6.2/topics/prop.test

https://stats.libretexts.org/Bookshelves/Introductory_Statistics/Book%3A_OpenIntro_Statistics_(Diez_et_al)./06%3A_Inference_for_Categorical_Data/6.01%3A_Inference_for_a_Single_Proportion

https://www.statisticshowto.com/success-failure-condition/

Conclusions:

The proportion test is a possible statistical test that can be used to test the significance of the proportion of success/failures in the modified hand compared to the original hand.

Action items:

-Discuss with group if statistical analysis is necessary and/or feasible for qualitative testing data.

Qualitative testing protocol 12/6/21

SHREYA SREEDHAR - Dec 12, 2021, 3:59 PM CST

Title: Statistical analysis testing for qualitative testing

Date: 12/6/21

Content by: Shreya

Present: Shreya

Goals: To draft testing protocol for qualitative testing

Content:

Qualitative testing protocol:

1. Start with a fully assembled version of the phoenix reborn hand and the various testing objects (Red Bull can, Bubly can, Arizona Iced Tea can, Hydro Flask) on a level surface.
2. Begin with the objects at full volume. Use the testing rod on the prosthetic hand and attempt to lift the object completely off the level surface. This should be completed with every object. Record a yes if it successfully lifted the object off the surface with no support and no if it was not able to lift the object.
3. Complete this testing with each object filled to its full volume.
4. Now add rubber fingertip grip additions to the pinky, ring, middle and index fingers. Repeat testing with the full volume and empty volume for each of the objects and record results.
5. Now to test the new prototype, disassemble the hand and reassemble it with the phalanx addition.
6. Complete testing of the new prosthetic using the empty and filled weights for each of the 4 objects.
7. Repeat steps of adding "page turner" additions to the pinky, ring, middle and index fingers on the prototype.
8. Complete testing again using filled and empty volumes and record data.

References: none

Conclusions:

This is the testing protocol that will be added in the final report appendix.

Action items:

-Add to final report

Tensioning systems 11/25/21

SHREYA SREEDHAR - Dec 12, 2021, 4:14 PM CST

Title: Tensioning systems

Date: 11/25/21

Content by: Shreya

Present: Shreya

Goals: To research different tensioning systems and which one would be most useful for our project.

Content:

Ratchet:

-It applies tension force which is based on the principle of various fixed mechanical lever ratio which as such cannot be altered.

-only a certain webbing length can be increased in tension.

-lever is needed.

Primitive System:

- This is a simple pulley system that tightens the string

-Tension cannot be easily reduced. This can possibly be a safety hazard for the user of the prosthetic.

Rope Pulley system:

-The most common tensioning option for lines over 50m long. There are pulleys, a rope, a rope break and connectors.

-Could potentially use this system and apply it at the back of the phalanges.

-In our case we would be using this with elastic string in the hand.

References:

https://www.slackshop.cz/en/stranka/10-how-to-choose-tensioning-system

Conclusions:

Although these systems are not used in the context of prosthetics, these same mechanics can be used in our tensioning system.

Action items:

-Determine which of these systems will be most useful for our prosthetic.

9/26/21 Pressed thumb design

SHREYA SREEDHAR - Sep 26, 2021, 6:03 PM CDT

Title: Pressed thumb design

Date: 9/26/21

Content by: Shreya S.

Present: N/A

Goals: Create a feasible design to improve cylindrical grip strength

Content:

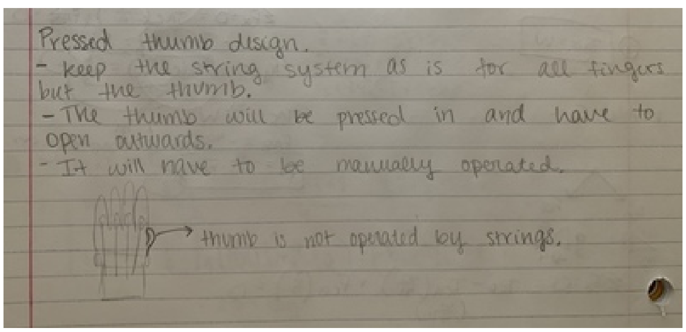
- only finger that would change is the thumb.

-Thumb would be manually moved outwards.

Conclusions/action items:

- would need to look into fabrication process. The thumb could utilize a spring system.

SHREYA SREEDHAR - Sep 26, 2021, 6:03 PM CDT



IMG_4153.jpg(1.1 MB) - download

9/26/21 hydraulics design

SHREYA SREEDHAR - Sep 26, 2021, 6:06 PM CDT

Title: Hydraulics design

Date: 9/26/21

Content by: Shreya S.

Present: N/A

Goals: Create a feasible design to improve cylindrical grip strength

Content:

- the hand would start off in a tight cylindrical grip. Then it can be pumped using air pressure outwards. When the user wants to close their grip, air pressure can be released and the grip would stay tight according to the object they are holding.

Conclusions/action items:

- would need to look into fabrication process and materials.

-make sure this can be done under the budget.

9/26/21 locking design

SHREYA SREEDHAR - Sep 26, 2021, 6:11 PM CDT

Title: locking design

Date: 9/26/21

Content by: Shreya S.

Present: N/A

Goals: Create a feasible design to improve cylindrical grip strength

Content:

- Add a locking mechanism to the base of the prosthetic. This will click the wires into place and lock in the hand.

-to unlock you can twist the lock back.

-Also want to try using a more plushy material covered in rubber so that it can sink into the material a little more.

Conclusions/action items:

- would need to look into how the locking mechanism would work.

-would be more of an addition rather than change.

Anatomy Research (10/2/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:24 PM CDT

Anatomy Research (10/2/21)

Title: Anatomy of the Hand

Date: 10/2/21

Content by: Sam Strachan

Present: Individual work

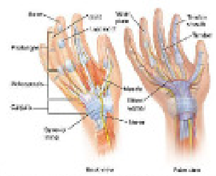
Goals: Record research on different parts of the hand so that they can be identified and communicate about hand anatomy correctly.

Link: https://www.fairview.org/patient-education/82181

http://www.oandplibrary.org/al/1985_02_022.asp

Author: Craig L Taylor, Ph.D., Robert J. Schwarz, M.D

Content:



- Categories covered in the article include: The Bones, Muscles and Tendons, The Palmar and Digital Pads, The Dorsal Integument, Nerve and Blood Supply, The Resting Hand Pattern, Fixed Hand Adaptations, Wrist Mechanics, Prehension Patterns, Mechanical Anatomical Basis of Prehension Patterns, Individuation of Digital Flexion Extension, Thumb Versatility Patterns,

Conclusions/action items:

This article is very detailed and includes tons of valuable information regarding "the anatomical basis of hand mechanics, from which it can be seen that normal hand function is the result not only of a highly complex and versatile structural arrangement but also of an equally elaborate and fully automatic system of controls."

Anatomy_Research_10_2_21_.pdf(92.9 KB) - download

Grip Mechanics Research (10/2/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:25 PM CDT

Grip Mechanics Research (10/2/21)

Title: Grip Mechanics Research

Date: 10/2/21

Content by: Sam Strachan

Present: Individual work

Goals: Record research on factors affecting grip force, anatomy mechanics, and other factors affecting the grip that might be useful for prosthetic design.

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4013140/

Author: Satyajit Ambike, Florent Paclet, Vladimir M. Zatsiorsky, and Mark L. Latash

Content:

- The article explores the effects of wrist position on the steady-state grip force and grip-force change during imposed changes in the grip aperture.
- An increase in the aperture resulted in an increase in grip force and its contraction resulted in a proportional drop in grip force. The apparent stiffness values were consistent across a wide range of wrist positions. These values were larger when the subjects performed the task with eyes open as compared to eyes-closed trials. They were also larger for trials that started from a larger initial aperture. After a sequence of aperture increase and decrease to the initial width, grip force dropped by about 25% without the subjects being aware of this. The results support the idea of back-coupling between the referent and actual digit coordinates. According to this idea, the central nervous system defines referent coordinates for the digit tips, and the difference between the referent and actual coordinates leads to force production.

Conclusions/action items:

- All of this scientific information leads me to the idea that subjects with limb loss will not experience this phenomena, which is a positive for the prosthetic grip strength, and negative at the same time. Their brain will not counteract the increasing force because there is not a measurable force being relayed to the brain to counteract. Additionally, the strain of wrist position is reported to not affect the strain of the grip strength.

Grip_Mechanics_Research_10_2_21_.pdf(64.4 KB) - download

Grip Strength Mechanics Research (10/2/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:26 PM CDT

Grip Strength Mechanics Research (10/2/21)

Title: Optimal Jamar dynamometer handle position to assess maximal isometric hand grip strength in epidemiological studies

Date: 10/2/21

Content by: Sam Strachan

Present: Individual work

Goals: Record research on factors affecting grip strength. How are these factors measured, how can they be improved? How can this information be incorporated into our design?

Link: https://pubmed.ncbi.nlm.nih.gov/23101534/

Author: Ulrike Sonja Trampisch, Julia Franke, Nina Jedamzik, Timm Hinrichs, Petra Platen

Content:

- In some studies, a subject's grip strength is taken to be the maximal grip strength achieved from measurements taken at several different dynamometer handle positions. However, little is known about the influence of these different positions on the measured grip strength. The aim of the study was to identify one standard handle position that could be used to assess the grip strength of all subjects.
- **Conclusion:** The results show that measurements taken at **a single standard handle position** are sufficiently accurate to assess grip strengths **for all** subjects.

Conclusions/action items:

- This leads me to believe that improving the grip strength of our prosthetic in one position will improve the grip strength for all other grip positions. I don't believe that the position itself will affect the performance of the hand, rather it is the overall performance of the hand that elicits good or bad results.

Grip_Strength_Mechanics_Research_10_2_21_.pdf(72.1 KB) - download

Unlimited Tomorrow Hand (9/19/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:27 PM CDT

Unlimited Tomorrow Hand (9/19/21)

Title: Unlimited Tomorrow TrueLimb

Date: 9/19/21

Content by: Sam Strachan

Present: Individual work

Goals: Research other companies that are producing 3D printed prosthetics

Link: https://www.unlimitedtomorrow.com/

https://singularityhub.com/2020/07/22/this-startup-is-3d-printing-custom-prosthetics-for-a-fraction-of-the-standard-cost/

Video Link: https://youtu.be/TpeqU6T8k1E Introducing TrueLimb

Content:

- It is an affordable, next-generation prosthetic arm that uses a custom remote-fitting process where the user never has to leave home.
- A 3D scan is taken of the arm to get a perfect fit of the prosthetic.
- The prosthetic is printed and assembled and then shipped to the client
- **Cost:** $7,995 (compared to others which cost $100,000)
- This is a bionic: It reads signals from nerves in the residual limb used to control motions like fingers bending.

Conclusions/action items:

- This hand is also a bionic rather than prosthetic, but the finger joints also appear similar to the Phoenix Reborn. It seems that many of these hands have the same design as our Phoenix hand, but many are automated. It makes me think that the solution to increasing grip strength lies in moving to an automated design.

Unlimited_Tomorrow_Hand_9_19_21_.pdf(123.9 KB) - download

Kinetic Hand (9/19/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:27 PM CDT

Kinetic Hand (9/19/21)

Title: eNable Kinetic Hand

Date: 9/19/21

Content by: Sam Strachan

Present: Individual work

Goals: Research other companies that are producing 3D printed prosthetics

Link: https://enablingthefuture.org/2020/11/13/introducing-the-new-3d-printed-kinetic-hand-design/

Content:

- This is another eNable product that consists of a different design.
- Notable differences in this design:
  - The palm has a more curved contour which I would expect to be better at gripping a cylinder because it has a greater surface area in contact with the cylinder
  - The palm and finger tips have a built in silicone grip to provide a high friction surface to maintain hold on an object

Conclusions/action items:
- This hand is a great comparison to our current hand because they are very similar in design, however small changes such as thumb location and palm surface will certainly make a huge difference in performance. This is important to keep in mind when designing, small changes can make a huge difference.

Kinetic_Hand_9_19_21_.pdf(174.7 KB) - download

Hero Arm 3D Print Bionic Hand (9/19/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:28 PM CDT

Hero Arm 3D Printed Bionic Hand (9/19/21)

Title: Open Bionics: Hero Arm

Date: 9/19/21

Content by: Sam Strachan

Present: Individual work

Goals: Research other companies that are producing 3D printed prosthetics

Link: https://openbionics.com/

Content:

- The Hero Arm is the world's first clinically approved 3D-printed bionic arm
- Applied to individuals with below-elbow amputation.
- Allows you to grab, pinch, high-five, fist bump, thumbs-up etc.
- Picks up signals from a user's muscles
- According to the website, it is the world's most affordable multi-grip prosthetic arm, with multi-grip functionality.
- Has haptic vibrations, beepers, buttons and lights to provide intuitive notifications.
- Can lift up to 8 kg
- The cost is somewhere between **$10,000 and $20,000** for a typical below the elbow solution.

Conclusions/action items:

- Despite being advertised as "affordable," this unit is still $10,000+ which is absurdly more expensive than our budget. It is still useful to consider its functionality. It appears very aesthetically pleasing, a component which could be incorporated into our design. This hand is a bionic rather than prosthetic, but the finger joints appear similar to the Phoenix Reborn.

Hero_Arm_3D_Printed_Bionic_Hand_9_19_21_.pdf(180.6 KB) - download

Client Meeting Research Notes (9/15/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:35 PM CDT

Client Meeting Research Notes (9/15/21)

Title: Client Meeting

Date: 9/15/21

Content by: Sam Strachan

Present: Full team

Goals: Ask questions about how the hand works, designs, materials, expectations etc.

Content:

- To buy a fitted prosthetic = $5000
- An eNable 3D printed prosthetic is in the range of $30
- Our challenge: Find a way to increase the grip strength
- All parts should be available at a craft store/hardware store
- All hands are scaled to 100% (very small), go upwards from there.
- Strings/elastics:
  - 1.75 mm printer filament, weedeater string.

Conclusions/action items:

- Essentially, we must increase the grip strength of the hand in a cylindrical position without increasing the cost and using materials that are very easily accessible by anyone.

Client_Meeting_Research_Notes_9_15_21_.pdf(69.6 KB) - download

3D Printer Filament Research (10/9/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:29 PM CDT

3D Printer Filament Research 10/9/21

Title: ABS Research

Date: 10/9/21

Content by: Sam Strachan

Present: Individual work

Goals: Explore the different properties of various 3D printer filaments, specifically ABS

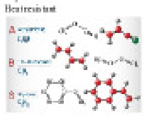
Link: https://www.simplify3d.com/support/materials-guide/properties-table/

https://making.engr.wisc.edu/3d-printers-2/

https://omnexus.specialchem.com/selection-guide/acrylonitrile-butadiene-styrene-abs-plastic

IEEE Citation: (2019, May 30). *Properties Table All-In-One 3D Printing Software* [Online]. Available: https://www.simplify3d.com/support/materials-guide/properties-table

Content:

- Ultimate Strength: 40 MPa
- Max Service Temperature: 98°C
- Coefficient of Thermal Expansion: 90 µm/m-°C
- Density: 1.04 g/cm^3
- Impact resistant
- Heat resistant
- 
- ABS is one of the most versatile materials available for 3D printing today
- Objects printed from ABS have high strength, flexibility, and durability.
- ABS, unlike PLA, is not biodegradable, only biocompatible.

Conclusions/action items:

- ABS is certainly an option for printing as it has good properties, however, it is less available to us in the Makerspace than PLA.

3D_Printer_Filament_Research_10_9_21.pdf(136.6 KB) - download

PLA Printer Filament Research (10/10/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:30 PM CDT

PLA Printer Filament Research (10/10/21)

Title: PLA Research

Date: 10/10/21

Content by: Sam Strachan

Present: Individual work

Goals: Explore the different properties of various 3D printer filaments, specifically PLA

Link(s): https://www.simplify3d.com/support/materials-guide/properties-table/

https://making.engr.wisc.edu/3d-printers-2/

https://dspace.mit.edu/bitstream/handle/1721.1/112940/Anderson_Physical%20and%20mechanical%20properties.pdf?sequence=1&isAllowed=y

IEEE Citation:

- (2019, May 30). *Properties Table All-In-One 3D Printing Software* [Online]. Available: https://www.simplify3d.com/support/materials-guide/properties-table
- Farah, Shady, et al. "Physical and Mechanical Properties of PLA, and Their Functions in Widespread Applications — A Comprehensive Review." Advanced Drug Delivery Reviews, vol. 107, Dec. 2016, pp. 367–92.

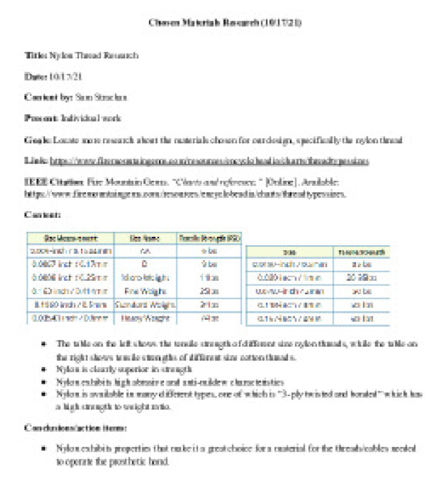
Content:

- Ultimate Strength: 60 MPa
- Max Service Temperature: 52°C
- Coefficient of Thermal Expansion: 68 µm/m-°C
- Density: 1.24 g/cm^3
- Heat resistant
- 

PLA_Printer_Filament_Research_10_10_21_.pdf(250.9 KB) - download

Chosen Materials Research (10/17/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:30 PM CDT



Chosen Materials Research (10/17/21)

Title: Nylon Thread Research

Date: 10/17/21

Content by: Sam Strachan

Present: Individual work

Goals: Locate more research about the materials chosen for our design, specifically the nylon thread

Link: https://www.firemountaingems.com/resources/encyclobeadia/charts/threadtypessizes

IEEE Citation: Fire Mountain Gems. "*Charts and references.*" [Online]. Available: https://www.firemountaingems.com/resources/encyclobeadia/charts/threadtypessizes.

Content:

Size Measurement	Size Name	Tensile Strength (lbs)
[illegible]	AA	[illegible]
0.0067 inch / 0.17mm	D	9 lbs
0.0096 inch / 0.25mm	Micro Weight	11 lbs
0.1[illegible] inch / 0.41mm	Fine Weight	25 lbs
0.1500 inch / 0.5mm	Standard Weight	24 lbs
0.0354 inch / 0.9mm	Heavy Weight	49 lbs

Size	Tensile Strength
[illegible]	[illegible]
0.020 inch / 1mm	20.38 lbs
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

- The table on the left shows the tensile strength of different size nylon threads, while the table on the right shows tensile strengths of different size cotton threads.
- Nylon is clearly superior in strength
- Nylon exhibits high abrasive and anti-mildew characteristics
- Nylon is available in many different types, one of which is "3-ply twisted and bonded" which has a high strength to weight ratio.

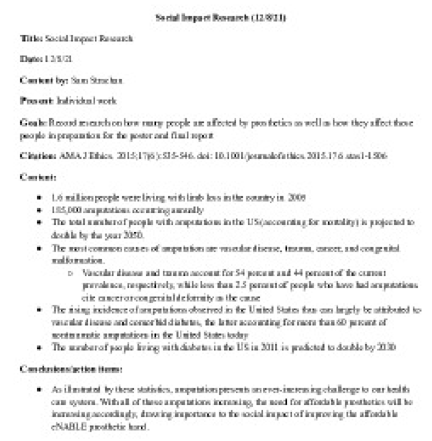
Conclusions/action items:

- Nylon exhibits properties that make it a great choice for a material for the threads/cables needed to operate the prosthetic hand.

Chosen_Materials_Research_10_17_21_.pdf(154.2 KB) - download

Social Impact Research (12/8/21)

SAMUEL STRACHAN - Dec 14, 2021, 1:42 PM CST



Social Impact Research (12/8/21)

Title: Social Impact Research

Date: 12/8/21

Content by: Sam Strachan

Present: Individual work

Goals: Record research on how many people are affected by prosthetics as well as how they affect these people in preparation for the poster and final report

Citation: AMA J Ethics. 2015;17(6):535-546. doi: 10.1001/journalofethics.2015.17.6.stas1-1506

Content:

- 1.6 million people were living with limb loss in the country in 2005
- 185,000 amputations occurring annually
- The total number of people with amputations in the US(accounting for mortality) is projected to double by the year 2050.
- The most common causes of amputation are vascular disease, trauma, cancer, and congenital malformation.
  - Vascular disease and trauma account for 54 percent and 44 percent of the current prevalence, respectively, while less than 2.5 percent of people who have had amputations cite cancer or congenital deformity as the cause
- The rising incidence of amputations observed in the United States thus can largely be attributed to vascular disease and comorbid diabetes, the latter accounting for more than 60 percent of nontraumatic amputations in the United States today
- The number of people living with diabetes in the US in 2011 is predicted to double by 2030

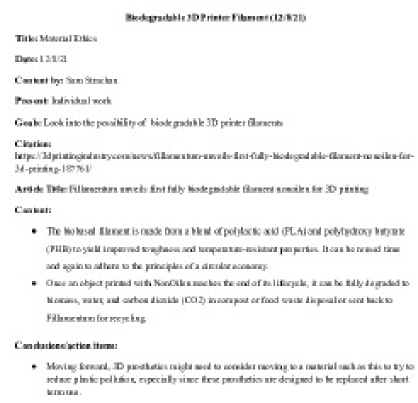
Conclusions/action items:

- As illustrated by these statistics, amputation presents an ever-increasing challenge to our health care system. With all of these amputations increasing, the need for affordable prosthetics will be increasing accordingly, drawing importance to the social impact of improving the affordable eNABLE prosthetic hand.

Social_Impact_Research_12_8_21_.pdf(64.2 KB) - download

Biodegradable 3D Printer Filament (12/8/21)

SAMUEL STRACHAN - Dec 14, 2021, 1:41 PM CST



Biodegradable 3D Printer Filament (12/8/21)

Title: Material Ethics

Date: 12/8/21

Content by: Sam Strachan

Present: Individual work

Goals: Look into the possibility of biodegradable 3D printer filaments

Citation:
https://3dprintingindustry.com/news/filamentum-unveils-first-fully-biodegradable-filament-nonoilen-for-3d-printing-187761/

Article Title: Filamentum unveils first fully biodegradable filament nonoilen for 3D printing

Content:

- The biobased filament is made from a blend of polylactic acid (PLA) and polyhydroxy butyrate (PHB) to yield improved toughness and temperature-resistant properties. It can be reused time and again to adhere to the principles of a circular economy.
- Once an object printed with NonOilen reaches the end of its lifecycle, it can be fully degraded to biomass, water, and carbon dioxide (CO2) in compost or food waste disposal or sent back to Filamentum for recycling.

Conclusions/action items:

- Moving forward, 3D prosthetics might need to consider moving to a material such as this to try to reduce plastic pollution, especially since these prosthetics are designed to be replaced after short term use.

Biodegradable_3D_Printer_Filament_12_8_21_.pdf(62.9 KB) - download

Ethical Considerations of Bioplastic Alternatives (12/8/21)

SAMUEL STRACHAN - Dec 14, 2021, 1:41 PM CST

Ethical Considerations of Bioplastic Alternatives (12/8/21)

Title: Material Ethics

Date: 12/8/21

Content by: Sam Strachan

Present: Individual work

Goals: Look into possible ethical concerns regarding the materials used in the project. Possible topics include plastic pollution and exploration of biodegradable 3D printer filaments.

Citation: Yaradoddi J.S. et al. (2019) Alternative and Renewable Bio-based and Biodegradable Plastics. In: Martínez L., Kharissova O., Kharisov B. (eds) Handbook of Ecomaterials. Springer, Cham. https://doi.org/10.1007/978-3-319-68255-6_150

Article Title: Alternative and Renewable Bio-based and Biodegradable Plastics

Content:

Types of Bioplastics

1. Non-biodegradable chemically synthesized plastics: Non-biodegradable and made from petrochemical resources such as polyethylene, polystyrene, polyvinyl chloride, etc.
2. Biodegradable plastics from renewable resources: Biomass materials such as starch from different sources are processed to show the property of biodegradation. Examples include starch blends made from starch and polyesters such as PLA or polyhydroxyalkanoate (PHA).
3. Biodegradable plastics from fossil resources: These are the plastics procured from fossil resources that have the property to biodegrade. With starch biodegradability and mechanical properties of the bioplastics can be enhanced. Examples are polycaprolactone (PCL), polybutylene succinate (PBS), and polybuthylene adipate terephthalate (PBAT).
4. Non-biodegradable plastics from renewable resources: These are the plastics where biomass is used for production of plastics without the biodegradation property. They are mostly made from bioethanol produced from sugar fermentation, biofuel such as polyethylene (bio-PE). Some other examples are polyvinyl chloride (bio-PVC), polyethylene terephthalate (bio-PET), or polypropylene (bio-PVC, bio-PET, bio-PP).

Conclusions/action items:

- This article revealed that there are a VAST amount of bioplastic alternatives out there with many different properties to explore. An action item is to now look for biodegradable 3D printer material.

Ethical_Considerations_of_Bioplastic_Alternatives_12_8_21_.pdf(70.8 KB) - download

Ethical Considerations of Materials Research (12/8/21)

SAMUEL STRACHAN - Dec 14, 2021, 1:41 PM CST

Ethical Considerations of Plastic Pollution (12/8/21)

Title: Material Ethics

Date: 12/8/21

Content by: Sam Strachan

Present: Individual work

Goals: Look into possible ethical concerns regarding the materials used in the project. Possible topics include plastic pollution and exploration of biodegradable 3D printer filaments.

Citation: Rhodes CJ. Plastic pollution and potential solutions. Sci Prog. 2018 Sep 1;101(3):207-260. doi: 10.3184/003685018X15294876706211. Epub 2018 Jul 19. PMID: 30025551.

Article Title: Plastic Pollution and Potential Solutions

Content:

- Estimated 8.3 billion tons of plastic has been made (ever)
- Between 1950 and 2015, a total of 6.3 billion tons of primary and secondary (recycled) plastic waste was generated, of which around 9% has been recycled, and 12% incinerated, with the remaining 79% either being stored in landfills or having been released directly into the natural environment.
- Although fears that such microparticles and their toxins may be passed via food webs to humans are not as yet substantiated, the direct ingestion of microplastics by humans via drinking water is a distinct possibility – since 92% of samples taken in the USA and 72% in Europe showed their presence
- Bioplastics only account for 0.5% of the total mass of plastics manufactured globally.

Conclusions/action items:

- It is clear that it would be morally correct to pursue a material that doesn't contribute to the pollution issue the world is experiencing. Considering that our product is all 3D printed plastic with a short use period, alternative materials that are more environmentally friendly should be considered. Bioplastics are still relatively new, however, their technology should be explored.

Ethical_Considerations_of_Materials_Research_12_8_21_.pdf(65.2 KB) - download

Ethical Considerations Research (12/8/21)

SAMUEL STRACHAN - Dec 14, 2021, 1:42 PM CST

Ethical Considerations Research (12/8/21)

Title: Ethics Research

Date: 12/8/21

Content by: Sam Strachan

Present: Individual work

Goals: Record research on factors relating to possible ethical issues, or things to take into account regarding the topic in preparation for the report and poster.

Citation: Baumann MF, Frank D, Kolb L-C, Stieglitz T. Obstacles to Prosthetic Care—Legal and Ethical Aspects of Access to Upper and Lower Limb Prosthetics in Germany and the Improvement of Prosthetic Care from a Social Perspective. Societies. 2020; 10(1):10. https://doi.org/10.3390/soc10010010

Content:

- Acceptance rates and user satisfaction are not only dependent on technical aspects, but also to a great extent on social and psychological factors.
- Limited access due to high costs of new prosthetic technology combined with rising costs in health care systems in general is a further issue we address.
- Looks at various social acceptance factors
- The experience of losing a limb, through either trauma or disease, can have a significant impact on a person's psychological reality. In addition to, potentially significant, pain, people with limb loss commonly experience reduced self-worth, heightened anxiety in social situations, depression, and even post-traumatic stress disorder
- Expectation management is another factor of vital importance in early rehabilitation stages.
- one important and often overlooked factor is the enthusiasm that can be created by providing a patient who lost a limb with a functional replacement

Conclusions/action items:

- Overall, this article was extremely eye opening to many of the factors to consider when designing and implementing prosthetics. For the most part, many of these recommendations are more for the doctor who is fitting the prosthetic, but one key takeaway for us is that different users need different things. Having customized function as well as appearance (color/design) are important factors to consider to make the patient happy with their product

Ethical_Considerations_Research_12_8_21_.pdf(73.3 KB) - download

Crocodile Hand Design (9/25/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:36 PM CDT

Crocodile Hand Design (9/25/21)

Title: Crocodile Hand Redesign

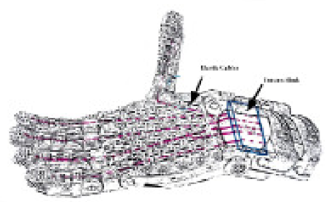
Date: 9/25/21

Content by: Sam Strachan

Present: Individual work

Goals: Brainstorm a new design to address the problem statement

Content: The idea behind this design is to reverse the direction of wrist movement associated with the opening and closing of the hand. The reason it is named the crocodile hand design is because the idea behind its function is based on the way that a crocodile jaw opens and closes. A crocodile jaw has a lot of force closing, but very little force opening. Similarly, you rarely use high amounts of force when opening your hand, but rather you use all of the force when closing your hand, this is also the problem we are addressing. Based on this idea, I redesigned the hand so that the elastic actually pulls the hand shut rather than open, thus by increasing the strength of the elastic, the grip will be strengthened. Wrist flexion would open the grip instead of close. So you could max out the strength of the elastic to match the maximum amount of wrist flexion force so that the user is still able to open the hand, but by relaxing, the hand closes with all of the force of the elastic and does not require user strain. To achieve this, the tensioner block is placed on the bottom of the hand so that wrist flexion is associated with the reverse movement of the hand. The thread and elastic are also reversed.



Crocodile_Hand_Design_9_25_21_.pdf(224.6 KB) - download

Adjustable Engagement Design (9/25/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:36 PM CDT

Adjustable Engagement Design (9/25/21)

Title: Adjustable Engagement Design

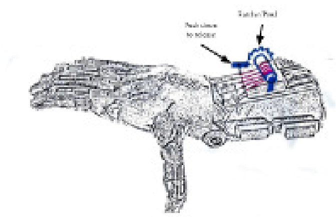
Date: 9/25/21

Content by: Sam Strachan

Present: Individual work

Goals: Brainstorm a new design to address the problem statement

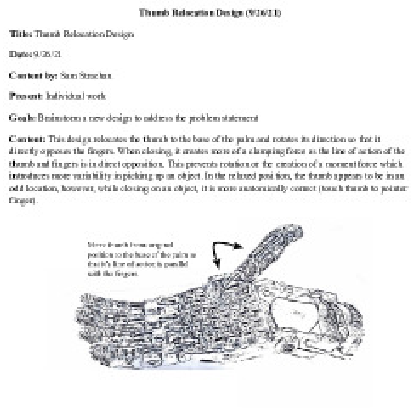
Content: This design aims to decrease user strain when holding an item for an extended period of time. The ratchet and pawl allows the user to quickly and easily tighten the contraction cables in the hand. This means the hand starts at a more closed position in the relaxed position, but requires less wrist flexion to reach the fully closed grip. There is less strain for the user to hold the hand shut at a position where the wrist is less bent, hopefully achieving the aim of this design. The spring loaded pawl can easily be released to allow the hand to return to the fully opened position.



Adjustable_Engagement_Design_9_25_21_.pdf(201.9 KB) - download

Thumb Relocation Design (9/26/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:37 PM CDT



Thumb Relocation Design (9/26/21)

Title: Thumb Relocation Design

Date: 9/26/21

Content by: Sam Strachan

Present: Individual work

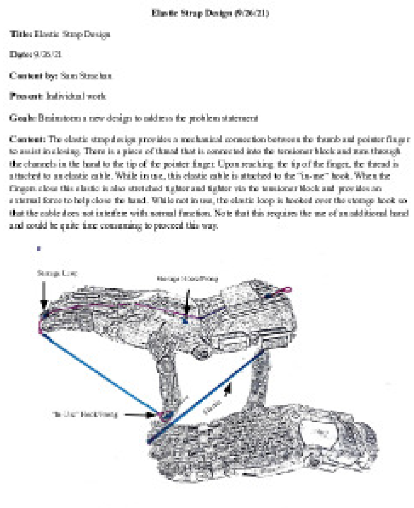
Goals: Brainstorm a new design to address the problem statement

Content: This design relocates the thumb to the base of the palm and rotates its direction so that it directly opposes the fingers. When closing, it creates more of a clamping force as the line of action of the thumb and fingers is in direct opposition. This prevents rotation or the creation of a moment force which introduces more variability in picking up an object. In the relaxed position, the thumb appears to be in an odd location, however, while closing on an object, it is more anatomically correct (touch thumb to pointer finger).

Thumb_Relocation_Design_9_26_21_.pdf(196.9 KB) - download

Elastic Strap Design (9/26/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:37 PM CDT



Elastic Strap Design (9/26/21)

Title: Elastic Strap Design

Date: 9/26/21

Content by: Sam Strachan

Present: Individual work

Goals: Brainstorm a new design to address the problem statement

Content: The elastic strap design provides a mechanical connection between the thumb and pointer finger to assist in closing. There is a piece of thread that is connected into the tensioner block and runs through the channels in the hand to the tip of the pointer finger. Upon reaching the tip of the finger, the thread is attached to an elastic cable. While in use, this elastic cable is attached to the "in-use" hook. When the fingers close this elastic is also stretched tighter and tighter via the tensioner block and provides an external force to help close the hand. While not in use, the elastic loop is hooked over the storage hook so that the cable does not interfere with normal function. Note that this requires the use of an additional hand and could be quite time consuming to proceed this way.

Elastic_Strap_Design_9_26_21_.pdf(270.1 KB) - download

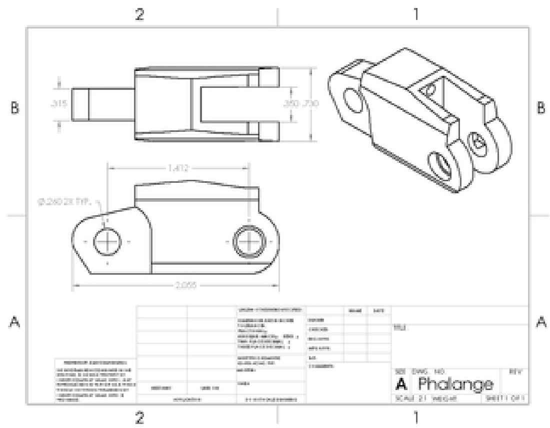
Solidworks Part File (10/19/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:42 PM CDT

Phalange.SLDPRT(235.5 KB) - download

Solidworks Drawing File (10/19/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:43 PM CDT



Phalange.JPG(183.3 KB) - download

SAMUEL STRACHAN - Oct 19, 2021, 9:43 PM CDT

Phalange.SLDDRW(131.3 KB) - download

Client Solidworks Phalanx File (10/19/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:44 PM CDT

knuckle1.SLDPRT(281.3 KB) - download

CAD Designing (10/10/21)

SAMUEL STRACHAN - Oct 19, 2021, 9:52 PM CDT

CAD Designing (10/10/21)

Title: CAD Designing

Date: 10/10/21

Content by: Sam Strachan

Present: Individual

Goals: To produce a 3D model of the new phalanx part to be used in the phalange extension design.

Content:

- I found some CAD parts for the hand available through the eNable website and Thingiverse, however due to issues with file conversion I was unable to import them into Solidworks to be adjusted. The approach I took instead was to model based off of the critical dimensions measured with a caliper. These included the hole size, slot and tab width, and overall length and width. From these I was able to get some other basic measurements so that it had the same organic look to it and produce the model shown.
- The distance from hole to hole on the new finger is 1.4 inches, extending the length of the fingers by that same amount.
- The pin holes and tab in slot connections are all exactly the same size making it easily integratable into the existing design without changing any other components.
- This will be printed out of PLA

Conclusions/action items:

- Part needs to be printed

CAD_Designing_10_10_21_.pdf(77.5 KB) - download

Updated Phalanx 10/31/21

SAMUEL STRACHAN - Oct 31, 2021, 12:07 PM CDT

Phalange.SLDPRT(338.1 KB) - download

Modified Knuckle (Position 1): 10/31/21

SAMUEL STRACHAN - Oct 31, 2021, 12:07 PM CDT

Original_Phalange.SLDPRT(295.6 KB) - download

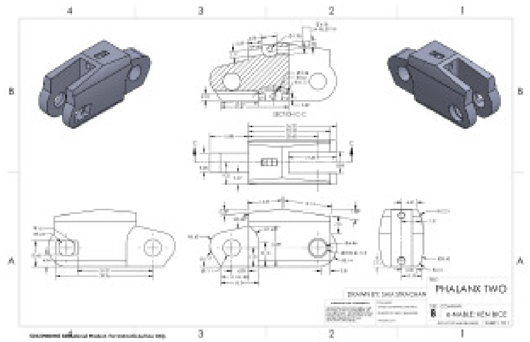
Short Pin

SAMUEL STRACHAN - Oct 31, 2021, 12:08 PM CDT

Knuckle_Pin_Short.ufp(75.9 KB) - download

Solidworks Drawing Modified Part (12/14/21)

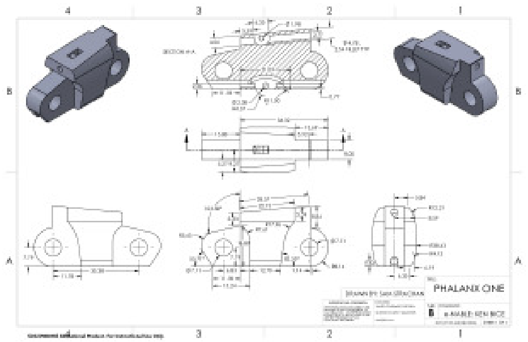
SAMUEL STRACHAN - Dec 14, 2021, 1:08 PM CST



Phalange_Drawing.pdf(174.6 KB) - download

Solidworks Drawings Original Part (12/14/21)

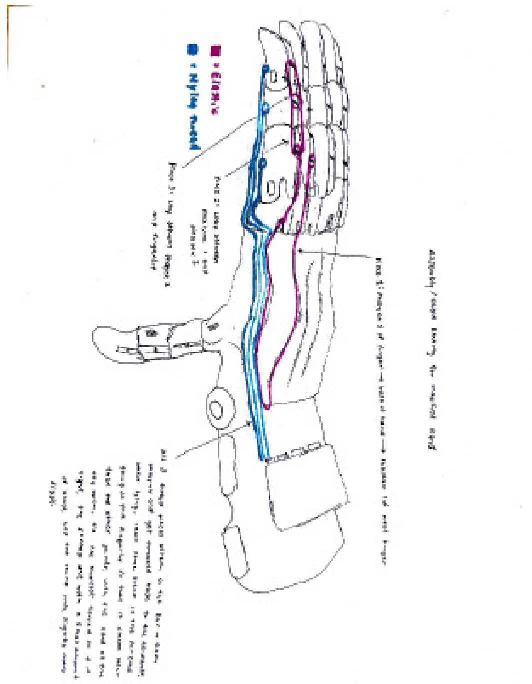
SAMUEL STRACHAN - Dec 14, 2021, 1:08 PM CST



Original_Phalange_Drawing.pdf(141.5 KB) - download

Cable Routing Guide11/18/21

SAMUEL STRACHAN - Nov 18, 2021, 11:19 PM CST

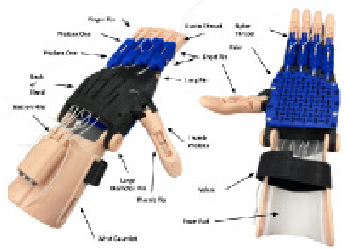


Cable_Routing_Guide.pdf(306.9 KB) - download

Assembly Guidelines (12/9/21)

SAMUEL STRACHAN - Dec 14, 2021, 1:10 PM CST

Assembly Guidelines

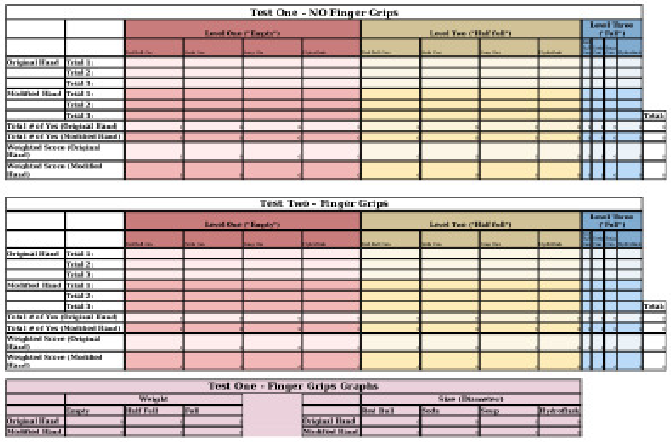


Materials		
(3) Tension Pins	(4) Phalanx Two	Velcro
(1) Wrist Gauntlet	(4) Finger Tip	Foam Pad
(1) Back of Hand	(10) Short Pin	Nylon Thread
(1) Palm	(2) Long Pin	Elastic Thread
(1) Thumb Phalanx	(2) Large Diameter Pin	Screws
(1) Thumb Tip	(4) Phalanx One	

Assembly_Guidlines.pdf(401.3 KB) - download

Testing Data Collection and Raw Analysis

SAMUEL STRACHAN - Nov 18, 2021, 11:20 PM CST



Test One - NO Finger Grips														
		Level One ("Empty")				Level Two ("Half Full")				Level Three ("Full")				
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Original Hand	Trial 1:													
	Trial 2:													
	Trial 3:													
Modified Hand	Trial 1:													
	Trial 2:													
	Trial 3:													Totals
Total # of Yes (Original Hand)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total # of Yes (Modified Hand)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Weighted Score (Original Hand)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Weighted Score (Modified Hand)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

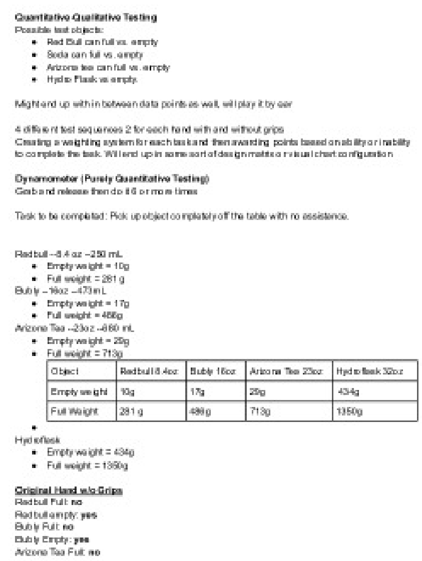
Test Two - Finger Grips														
		Level One ("Empty")				Level Two ("Half Full")				Level Three ("Full")				
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Original Hand	Trial 1:													
	Trial 2:													
	Trial 3:													
Modified Hand	Trial 1:													
	Trial 2:													
	Trial 3:													Totals
Total # of Yes (Original Hand)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total # of Yes (Modified Hand)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Weighted Score (Original Hand)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Weighted Score (Modified Hand)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Test One - Finger Grips Graphs									
	Weight					Size (Diameter)			
	Empty	Half Full	Full			[illegible]	Soda	Soup	Hydroflask
Original Hand	[illegible]	[illegible]	[illegible]		Original Hand	[illegible]	[illegible]	[illegible]	[illegible]
Modified Hand	[illegible]	[illegible]	[illegible]		Modified Hand	[illegible]	[illegible]	[illegible]	[illegible]

Testing_Data_Collection.xlsx(12.7 KB) - download

Initial Thoughts on Testing Protocol

SAMUEL STRACHAN - Dec 14, 2021, 1:11 PM CST



Quantitative Qualitative Testing
Possible test objects:

- Red Bull can full vs. empty
- Soda can full vs. empty
- Arizona tea can full vs. empty
- Hydro Flask vs empty

Might end up with in between data points as well, will play it by ear

4 different test sequences 2 for each hand with and without grips
Creating a weighting system for each task and then awarding points based on ability or inability to complete the task. Will end up in some sort of design matrix or visual chart configuration

Dynamometer (Purely Quantitative Testing)
Grab and release then do it 5 or more times

Task to be completed: Pick up object completely off the table with no assistance.

Redbull ~8.4 oz ~250 mL

- Empty weight = 10g
- Full weight = 281 g

Bubly ~16oz ~473 mL

- Empty weight = 17g
- Full weight = 486g

Arizona Tea ~23oz ~680 mL

- Empty weight = 29g
- Full weight = 713g

Object	Redbull 8.4oz	Bubly 16oz	Arizona Tea 23oz	Hydroflask 32oz
Empty weight	10g	17g	29g	434g
Full Weight	281 g	486 g	713g	1350g

Hydroflask

- Empty weight = 434g
- Full weight = 1350g

Original Hand w/o Grips
Redbull Full: **no**
Redbull empty: **yes**
Bubly Full: **no**
Bubly Empty: **yes**
Arizona Tea Full: **no**

Testing_Protocol_Data.pdf(49.8 KB) - download

Contribution of the Ulnar Digits to Grip Strength

JAIME BARAJAS - Sep 15, 2021, 4:18 PM CDT

Contribution of the Ulnar Digits to Grip Strength

by Jennifer Methot, Shrikant J Chinchalkar, and Robert S Richards.

- Purpose of this experiment was to determine how the ulnar digits create an increase in overall grip strength of the hand.

- Test subjects included 25 men and 25 women for a total of 100 hands to test for grip strength.

- As expected, the dominant hand on each subject was stronger in grip strength

- Even with testing the dominant and non-dominant hand, grip strength decreased by a significant 33% with just the pinky excluded. Grip strength then decreased an average of 54% from full strength when the ring finger was also restricted.

- The results are that as the ulnar digits were excluded, grip strength dropped significantly.

- The pinky although seemingly useless, is one of the most important fingers in overall hand grip strength.

- Exclusion of the Ulnar region resulted in an overall 54% grip strength.

Takeaway

- How can we improve the strength or design of the pinky?

- Is the pinky flawed in an way that can be improved?

- Since the Ulnar region is what improves overall grip strength, how can it be 3D printed and designed for optimization?

Citation:

Methot, Jennifer et al. “Contribution of the ulnar digits to grip strength.” *The Canadian journal of plastic surgery = Journal canadien de chirurgie plastique* vol. 18,1 (2010): e10-4.

JAIME BARAJAS - Oct 19, 2021, 11:55 PM CDT

Title: Contribution of the Ulnar Digits to Grip Strength

Date: 9/15/2021

Content by: Jaime Barajas

Present:

Goals: To understand how the function of the ulnar digits increase the total force of the grip in the hand.

Content:

Contribution of the Ulnar Digits to Grip Strength

by Jennifer Methot, Shrikant J Chinchalkar, and Robert S Richards.

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Conclusions/action items:

Takeaway

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Citation:

Methot, Jennifer et al. “Contribution of the ulnar digits to grip strength.” *The Canadian journal of plastic surgery = Journal canadien de chirurgie plastique* vol. 18,1 (2010): e10-4.

Biology of the Hand

JAIME BARAJAS - Sep 15, 2021, 5:10 PM CDT

How do Hands Work?

- Hands consist of 27 bones, 8 carpal bones, 5 metacarpal bones, and 14 phalanges

- There are over 30 muscles in the hand.

    - There is adduction which allows us to pull our fingers together and abduction which allows us to spread our fingers

- There is precision grip and power grip

    - What we want is power grip but with allowed precision so that the user is not constantly over flexing the hand

- One important aspect of the power grip is being able to position the thumb opposite of the fingers to allow for grip on an object from both sides.

- The smoother the surface is, the harder it is to grip an object

    - If the prosthetic fingertips are too smooth or are free to move then it may be difficult to grip heavy objects.

- Tendon sheaths provide lubricant to the tendons so that flexing the fingers becomes easier

    - Less friction means less strain to flex the hand

- Although tendon sheaths exist to reduce friction, the carpal tunnel houses the tendons so that it provides a base for them to flex from.

    - Improving the carpal tunnel will allow for stronger flexion

Citation

`InformedHealth.org [Internet]. Cologne, Germany: Institute for Quality and Efficiency in Health Care (IQWiG); 2006-. How do hands work? 2010 Aug 31 [Updated 2018 Jul 26]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK279362/`

JAIME BARAJAS - Oct 20, 2021, 12:16 AM CDT

Title: Biology of the Hand

Date: 9/15/2021

Content by: Jaime Barajas

Present:

Goals: To understand the overall biology of the hand

Content:

- Hands consist of 27 bones, 8 carpal bones, 5 metacarpal bones, and 14 phalanges

- There are over 30 muscles in the hand.

    - There is adduction which allows us to pull our fingers together and abduction which allows us to spread our fingers

- There is precision grip and power grip

    - What we want is power grip but with allowed precision so that the user is not constantly over flexing the hand

- One important aspect of the power grip is being able to position the thumb opposite of the fingers to allow for grip on an object from both sides.

Conclusions/action items:

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InformedHealth.org [Internet]. Cologne, Germany: Institute for Quality and Efficiency in Health Care (IQWiG); 2006-. How do hands work? 2010 Aug 31 [Updated 2018 Jul 26]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK279362/

Current Concepts of the Anatomy of the Thumb Trapeziometacarpal Joint

JAIME BARAJAS - Oct 18, 2021, 5:40 PM CDT

Current Concepts of the Anatomy of the Thumb Trapeziometacarpal Joint

By: J Ollie Edmunds

Prehension- Moving the hand to an object and shaping the hand in anticipation of grabbing the object, and then actually grabbing the object.

- The thumb determines prehension in the hand and is very useful in the hand grip of **Opposition.**

- Opposition is the ability to put the thumb directly opposite of the other four digits.

- Opposition allows for a better grip by creating a greater degree of force on whatever object is being grabbed.

Citation: Edmunds JO. Current concepts of the anatomy of the thumb trapeziometacarpal joint. J Hand Surg Am. 2011 Jan;36(1):170-82. doi: 10.1016/j.jhsa.2010.10.029. PMID: 21193137.

JAIME BARAJAS - Oct 20, 2021, 12:22 AM CDT

Title: Current Concepts of the Anatomy of the Thumb Trapeziometacarpal Joint

Date: 10/18/2021

Content by: Jaime Barajas

Present:

Goals: To understand the rotation of the thumb to improve the degree of freedom in the current prosthetic

Content:

Current Concepts of the Anatomy of the Thumb Trapeziometacarpal Joint

By: J Ollie Edmunds

Prehension- Moving the hand to an object and shaping the hand in anticipation of grabbing the object, and then actually grabbing the object.

- The thumb determines prehension in the hand and is very useful in the hand grip of **Opposition.**

- **Opposition** is the ability to put the thumb directly opposite of the other four digits.

- Opposition allows for a better grip by creating a greater degree of force on whatever object is being grabbed.

Conclusions/action items:

- By creating opposition using the thumb, a greater degree of force may be made to the cylindrical object we are trying to pick up.

Citation: Edmunds JO. Current concepts of the anatomy of the thumb trapeziometacarpal joint. J Hand Surg Am. 2011 Jan;36(1):170-82. doi: 10.1016/j.jhsa.2010.10.029. PMID: 21193137.

Bionicohand

JAIME BARAJAS - Oct 20, 2021, 12:34 AM CDT

Title: Bionicohand Competing Design

Date: 10/19/2021

Content by: Jaime Barajas

Present:

Goals: To explore a competing design and its working 3D printed model

Content:

- The bionicohand project is a project started by a single man in France who wanted to make cheaper electric powered prosthetics.

- He implemented an arduino into a 3D printed prosthetic using muscle sensors to make the actuators close and cause tension in the fingers

- The final product was around $158 dollars

Conclusions/action items:

- We would like to keep our prosthetic very affordable for our users so $158 is a little out of our price range, but is not that expensive compared to other myoelectric prosthetics.

Unlimited Tomorrow

JAIME BARAJAS - Oct 20, 2021, 12:48 AM CDT

Title: Unlimited Tomorrow Competing Design

Date: 10/19/2021

Content by: Jaime Barajas

Present:

Goals: To understand how a competing design may help understand where our flaws lie.

Content:

- Unlimited tomorrow's prosthetic weighs roughly 1.5 pounds and is customized to the user's skin tone to make it aesthetically suitable to the user's wants.

- The prosthetic also implements use of electronics to flex the arm movement.

- Looking at the prosthetic it seems to have a better closure around the user's forearm.

- Rather than putting the sensors in specific places on the residual limb, the prosthetic has 36 sensors on it so that it sense muscle flexion regardless of where the user has placed the prosthetic when putting it on.

- The prosthetic also provides vibrations so the user can feel when the prosthetic makes contact with an object.

Conclusions/action items:

- The prosthetic is too complex with sensors and motors implemented. We are trying to keep the simplicity of building and using the prosthetic throughout the project.

Design Ideas

JAIME BARAJAS - Sep 27, 2021, 5:53 PM CDT

Design Ideas - Jaime Barajas

1.) Adjustable tension hand.

- Idea comes from a vise-grip wrench that you can spin a little knob and it increases the amount of claspin pressure around an object.

- You could also be able to adjust which side of the hand has more tension.

    - If hands have tendons and muscles on both the front ad back of the hand, why not implement tension in both the front and back of the hand.

    - There could be a knob that adjusts the tension on the chords of the hand and it could increase pressure on the grip or decrease pressure depending on the grip needed.

    - This would allow for adduction and abduction

2.) Making the thumb like a ratchet to be able to click it into different positions perpendicular to the digits to allow for different uses of the thumb.

    - This would allow for flexion and extension of the thumb at different heights for a grip with the thumb over the digits or with the thumb beside the digits.

3.) Have a ratchet locking system for the digits that would open upon press of a button under the wrist.

    - This would allow for if you were holding something like a soda can, when you wanted to put it down with one hand you press your wrist against the table and then the hand would unclasp around the soda can.

    - If it is someone with a need of only one prosthetic, they are free to use their other hand to press the button.

    - Of course this feature cannot constantly be on as it could become annoying for the user.

4.) A strap that starts from the shoulder that allows for more muscle use and stronger grip

    - When we extend our arms we extend the length between our hands and our shoulders. If the length is increasing, if we added strings, tension would increase and could be even stronger and more energy efficient than flexion of the wrist.

5.) A silicon like filament could be used for half of the finger to have grip on the inner hand where needed.

    - It could pose difficult but half of the finger could be taken off and then molded with silicon and then have attachment points on the 3D printed half of the finger and they could be put together.

    - ABS plastic is cheaper than silicon but has some similar properties

6.) A cheaper way to improve grip could also be to just further improve the little finger grips that Ken provided us.

Make inner hand curved, change placement of the thumb, and increase friction/surface area.

Design Specifications and Improvements

JAIME BARAJAS - Dec 14, 2021, 2:33 PM CST

Title: Design Specifications and Improvements

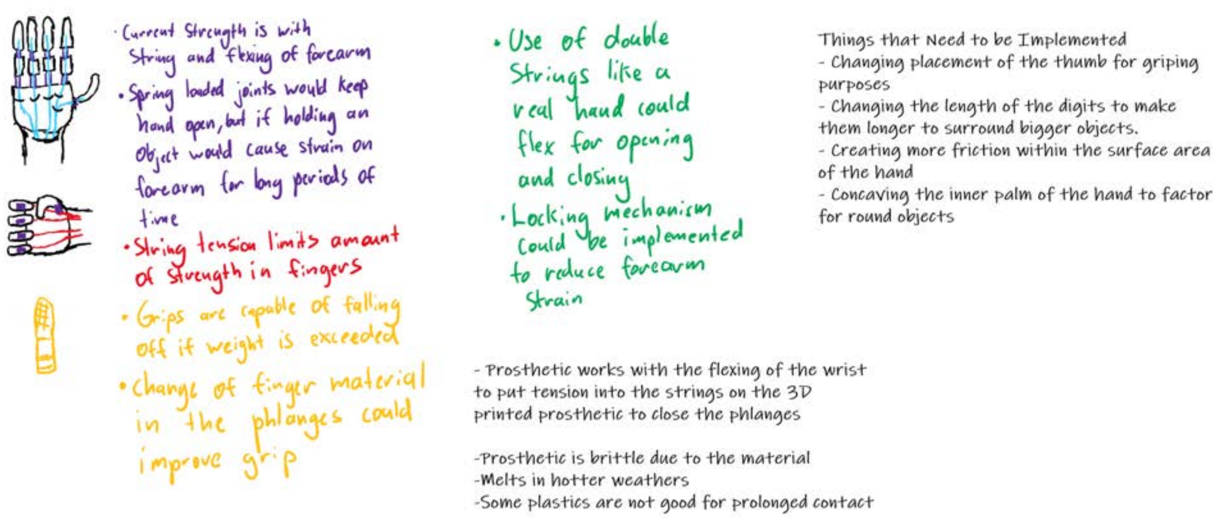
Date: 12/14/2021

Content by: Jaime Barajas

Present: Jaime Barajas

Goals: To come up with ideas and specifications that the prosthetic hand needed to be improved upon.

Content:

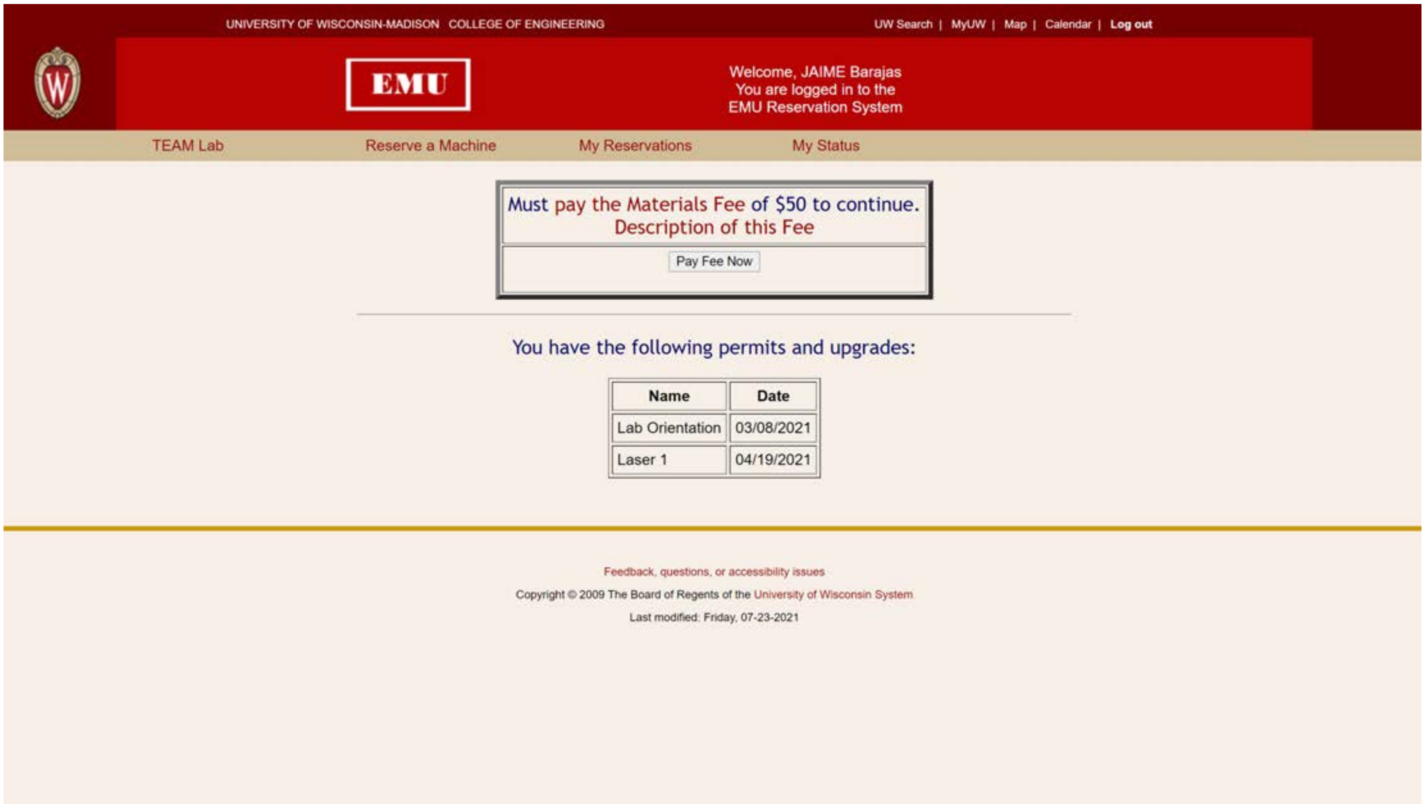


- I wrote this at the very beginning of the semester but forgot to put it into my lab archives.

Conclusions/action items: Moving forward, the group should improve upon increasing the surface area of the hand to increase friction and work on the tensioning system. The team should also work on maintaining the cost efficiency of the prosthetic.

Proof of Lab and Laser Cutting Training

JAIME BARAJAS - Oct 20, 2021, 12:09 AM CDT



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

ALEXANDER VAZQUEZ - Sep 27, 2021, 3:06 PM CDT

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: