The Million Hands Platform

Master of Engineering Capstone

2017-2018

April 23, 2018

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1. Abstract

Million Hands aims to build an online platform with a library of comfortable and low-cost prosthetic hands for users to choose from, customize, and order. The prostheses industry has expanded with the medical device industry over the past few decades; however, a lack of functional, customizable, and low-cost upper limb prostheses persists. These user needs require a specialized, targeted product to enrich the lives of those with upper limb trauma or congenital limb differences. The Million Hands platform tackles this market deficiency by incorporating key features to meet each user need. Users will be able to choose their desired prosthetic from a library of designs. The platform then uses a 3D scan of the user's hand, which can be executed and uploaded using available mobile phone technology, to perform an automated fitting of the user's desired prosthetic. This ensures perfect fit and customizability. The automated fitting process also allows users to bypass expensive professional fitting processes, thereby reducing cost. 3D printed parts will be used to customize each order while minimizing cost. Currently, Million Hands is developing a library of available devices for this platform.

2. Project Development

A. Industry Analysis

i. Expansion of prosthetic user group requires new prosthetic technology development

As the user group for prosthetic devices has expanded, prosthetics must be redesigned to address the variety of needs within the population. The prosthetic industry is a multidimensional space with social, technological, economic and regulatory dimensions. The social trends in the prosthetics industry have changed over the last few decades. Prosthetics were originally designed for male war veterans, with hooks as a means of assistive shape and with a masculine aesthetic (Figure 1) (Serlin, 2002). However, anyone, including women and children, requiring upper limb assistive devices now seek prosthetics. There are currently over 350,000 upper limb amputees in the United States, with 50,000 new amputees each year (ISHN, 2014). Each patient requires clinical care and a prosthetic or assistive device to enhance their quality of life. Nearly 70% of upper limb amputations are distal to the elbow (ISHN, 2014). Additionally, research has shown that device acceptance by a patient requires that the prosthesis "must be comfortable, functional and have a pleasing appearance" (Millstein et.al., 1986). The demand for a broader range of prosthetics has increased with the needs of this expanded user group, creating an opportunity for Million Hands to develop new technology in this area.

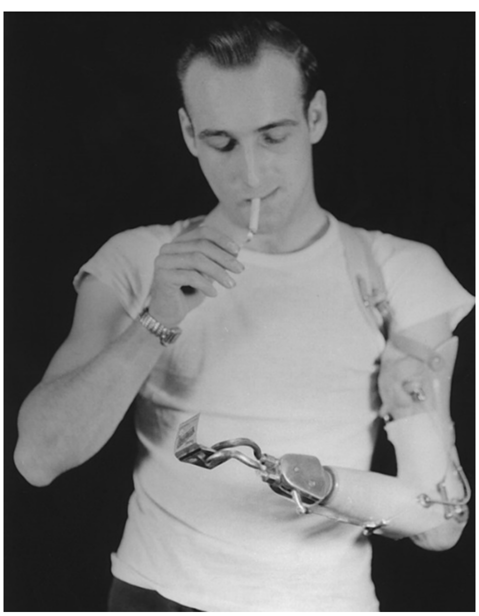


Figure 1: 1950's upper limb prostheses were masculine, and primarily designed for veterans who lost limbs in combat (Serlin, 2002).

ii. Despite medical industry growth, insurance policies fail to make prosthetics affordable

The medical device industry, which includes prosthetic technology, is growing rapidly, which creates an opportunity for innovations. According to an IBISWorld Industry report, 8.7% of the newest products are for patient recovery and noninvasive devices. This segment is projected to grow at 2.9% from 2017-2022. Large medical device companies will continue to develop their R&D departments and seek new technologies by acquiring small startup companies that concentrate on new and unmet needs (Curran, 2017). This provides a good opportunity for startup companies and for the commercialization of prosthetic hands. One unmet need in the prostheses industry is affordability. Prosthetics cost $2000-$20,000, and very few health insurance agencies cover upfront and maintenance costs of these devices (Smith, 2013).

iii. Minimal regulatory requirements for prosthetics encourages new technology commercialization

FDA approval is only required for prostheses if the prosthetics company makes a strong claim that the device improves the overall health of the user (Sastry, 2014). Most prosthetics are viewed as tools or assistive devices to be used at the discretion of the patient and thus do not need FDA approval for production. This characterization allows for faster development and commercialization of the product. By defining Million Hands prostheses as assistive devices, there is no need for FDA approval.

iv. Competitive analysis confirms market gap of low-cost, highly functional, and customizable devices

Despite technological advances in prosthetics, a survey revealed that only 70-75% of prosthetic users were satisfied with their prosthesis. Only 27-56% percent of upper limb prosthesis reported using their prosthesis (McGimpsey & Bradford 2014). This implies a broad desire for improvement in prosthetic quality and comfort among current upper limb amputees and prosthesis wearers.

Several products' prices, functional capabilities, and aesthetics were analyzed to help identify where the Million Hands product could make the greatest impact. Table 1 shows upper limb assistive prosthetics currently on the market, their functions, and their prices. This data shows a strong correlation between cost and functionality; functional prosthetics are much costlier than those designed purely for aesthetic purposes. Furthermore, most devices are custom-fit and manufactured, resulting in higher costs. There were no products with high functionality at low-cost; this is the need the team aims to fill.

Table 1: Competitive Analysis of Prostheses

Company	Product	Description	Functionality	Price
TRS Prosthetics	Pedi Pro Cuff	Highly functional harness; attachments not included.	High	$650
Enable Hands	Open Source 3D printed hands	Passive, wrist-controlled gripping; large assembly time required	High	$30-$500
Bebionic	Powered hand for amputees	Very good fine motor skills; no powerful lifting	High	$11,000
Touch Bionics	iDigits Quantum	Partial Hand powered prosthetics	High	~$10000
Touch Bionics	Living Skin	Cosmetic silicone prosthesis	Low	~$5000
Open Bionics	Children's prosthetics with decals	Gripping only; aesthetic focused	Low	$1500
Tact Hand	Open source 3D printed hand	Myoelectric possible for 3 gripping patterns	Medium	$250
Cyborg Beast	Open source 3D printed hand	Passive crude gripping	Low	$50

Analysis of the devices in Table 1 shows custom features are most responsible for price increases.

The team investigated the relationship between functionality and aesthetic appearance as well (Figure 2). Many items on the market that are high in function with low aesthetics.

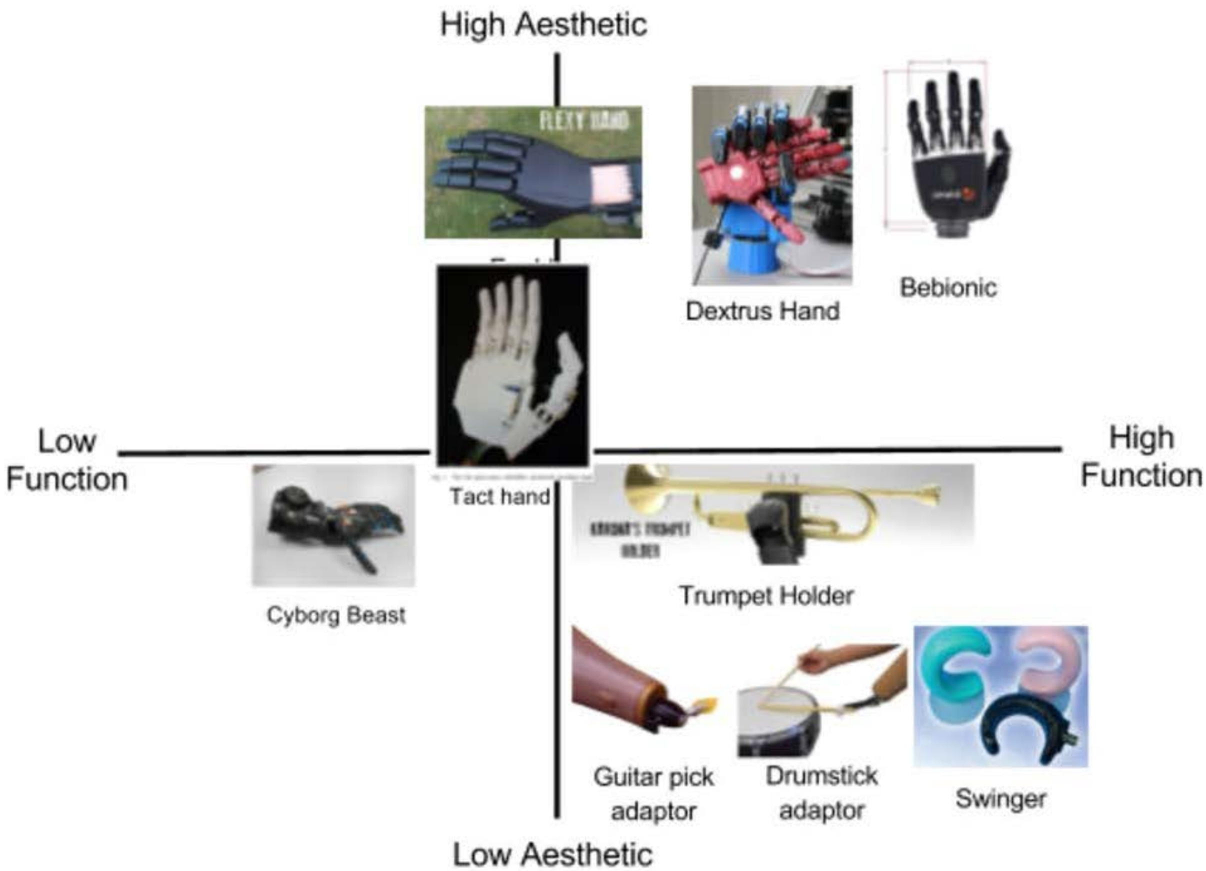


Figure 2: A graph of aesthetic appeal versus functionality. A trade-off between the two qualities exists with most products on the market. As proven with conjunction with Table 1, hands with both aesthetic and functionality tend to be prohibitively expensive.

Thus, the Million Hands product must be high performance and low in price, with a concentration on aesthetic appearance as well (Figure 3).

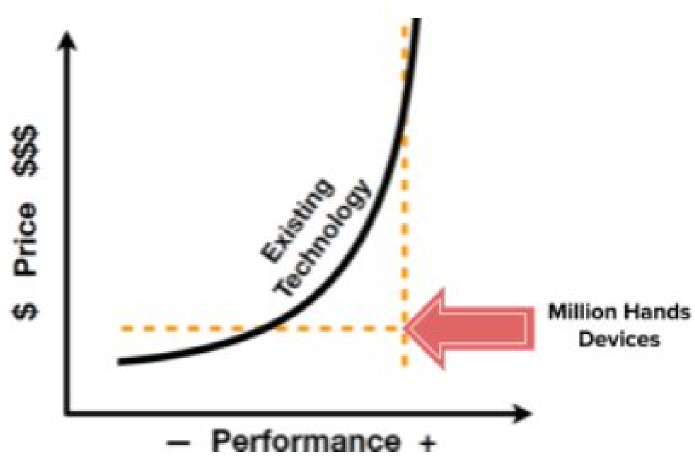


Figure 3: Price-performance space targeted by Million Hands. The goal is to develop low-cost but highly functional prosthetics.

B. User Need Analysis

Human centered design is a product development practice to gather and analyze user needs data. This method emphasizes interviewing many potential users of the product or service to identify problems they face, deduce their most important unmet needs, and design a product around these specifications, rather than building a product and then asking users to evaluate it. Research has shown that user involvement early in a development process results in both "system success and user satisfaction" (Kujala, 2010). Human centered design helps build a foundation for design thinking and developing a more impactful product (Dym, Agogino, et. al., 2005). Academic research on the prostheses industry confirms Million Hands' findings that currently technology is not meeting user needs as shown by "prosthesis rejection, non-wear, and user reports of pain and challenging activities" (Benz et. al., 2010). Million Hands employed these strategies to develop a novel and impactful product.

i. Interviews reveal users want customizable, functional, and low-cost features

Interviews with major stakeholders helped identify the primary user needs the Million Hands platform must achieve: customizability, functionality, and low monetary cost to users. These stakeholders include doctors, users, prosthetic makers, and researchers.

Identification of the needs for a customizable and highly functional product arose through interviews with professional experts in the prosthetics industry. According to UCSF's specialists, amputees can be divided into two groups: those with congenital hand differences and upper-limb amputees. Each group has specific upper limb anatomy differences including bone and tendon development, which creates a unique hand shape that the prosthetic must fit. The team endeavors to address this challenge and develop a diverse design library which can cater to the needs of both populations through a modular approach.

The applications each group requires from their devices differ as well. Those with congenital hand differences only require prosthetics for specific activities, such as playing instruments, whereas those who have amputations benefit from a prosthetics for basic daily tasks. Consequently, the product needs to provide options in response to various hand conditions that can be customized in fit as well as function.

To achieve a high level of functionality, the use of electrically powered, myoelectric, prosthetics with intuitive operation methods must be developed. According to Richard Nguyen, Clinical Manager of UCSF Orthopedic Institute, the acceptance rate of myoelectric prosthetics is low relative to passive prosthetic acceptance rate (See Appendix A). This rate can be improved by implementing a process wherein patients start with a passive or body powered prosthetic and then upgrade to a myoelectric powered prosthetic, without changing their initial prosthetic. Comparison of advances in body-powered prostheses show that additional benefits include "silent action, light weight, moderate cost, durability, reliability, rough sensory feedback about the positioning of the terminal device, and simple operational" (Hashim et.al., 2018). Thus, it is important to make a variety of designs available that allows the user to seamlessly upgrade from a body powered, or passive prosthetic. The low acceptance rate of myoelectric-controlled prosthetics can also be attributed to their steep learning curve; incorporation of intuitive actuation methods (methods to open and close the prosthetic hand) such as tensing the forearm muscle to operate the prosthetic grip, can address this issue. This can also be improved by implementing haptic feedback on the device, allowing the user to feel the force applied while gripping.

The need for a low-cost system was confirmed by UCSF Director of Orthotics and Prosthetics Matthew Garibaldi (See Appendix B). Garibaldi stated that current prosthetics are difficult to fit to each patient's unique arm shape; the patient must make many appointments to adjust the device. Most insurance companies charge the fitting process on a single bill, which includes all appointments, hence making the process very expensive. By improving the fitting process, the overall cost is reduced.

ii. Additional interview insight emphasizes importance of anthropomorphic designs in future work

Garibaldi also mentioned that there is a lack anthropomorphic myoelectric prosthetics available on the market, thus creating a gap in user satisfaction (See Appendix B). Anthropomorphic prosthetics look like natural human hands and, with myoelectric technology, can be activated through signal processing from flexing one's muscle. It would be greatly beneficial to have anthropomorphic myoelectric prototypes in future iterations of the myoelectric designs in order to fill this market gap.

iii. Million Hands' online platform fulfills user need for customizable, functional and low-cost prosthetics

Human centered design research has helped the team define a solution that will best meet user needs: the Million Hands project will build an online platform for users to easily customize and build their own prosthetic hands. The platform will consist of an automated fitting process and a store for purchasing prosthetic designs. This platform will allow users to upload a 3D scan of their hand to use to digitally test the fit of their prosthetic. They will be able to pick out a prosthetic shape for their unique condition with the technological capabilities to meet their desired function. By eliminating fitting appointments with prosthetists, the cost to the user will be lower. The team will design and supply prosthetic components to build these devices.

To create this product, the team has defined clear intermediate goals and product requirements. First, customizability of prosthetics must be maintained for a variety of hand sizes and functions. Through thoughtful brainstorming and conceptualization sessions, the team has decided that the products must be modular. This allows users to pick and choose key features of their prosthetic while also allowing the team, as suppliers, to mass produce each feature rather than building one-off products for each user's unique request. In addition, the user should be able to know what size prosthetic parts to buy to ensure comfort. Recent advances in 3D scanning technology have made it possible to perform 3D scans using one's cell phone. The Million Hands platform will allow the user to upload a scan of their hand and simulate how parts will fit the user.

Second, the Million Hands platform must maintain its low-cost focus. Through analysis of current technology and user interviews, the team plans to sell passively actuated (non-electronic) prosthetics for under $250 while actively actuated prosthetics including myoelectric designs will be sold for under $1000. Compared to the cost of existing prosthetics on the market (Refer Table 1), the Million Hands product provides a significant cost benefit for the user. The modular product design will help achieve this goal by allowing users to build a prosthetic that fits their budget. Affordable manufacture methods will be employed as well (See Section 2. B. iv.)

Lastly, functionality must be maintained in the Million Hands' products. The products must add value to the users' lives and be reliable. To do so, the team will design and iterate the devices by working directly with users. The team plans to prototype designs, test with potential customers, and make changes before finalizing designs to sell online. This strategy allows the team to quickly and continuously iterate the designs based on direct user feedback until the highly functional products are developed. This portion of work is currently underway; the Million Hands team is working with a patient with toxic shock syndrome to create a passively actuated finger design. Additionally, the team is also establishing research development with patients at UCSF hospital. After designing the products, the team will ensure reliability through systematic durability testing including drop tests, temperature cycling, and stress testing.

iv. Literature and physical analysis of materials in prosthetic industry show 3D printing may reduce costs

3D printing and printable plastics (like Ninjaflex, PLA, etc.) have evolved to be a convenient, low-cost alternative for the design of prosthetics. Many companies employ new materials such as silicon and carbon fiber to improve mobility and stability (O'Connell, 2017, History of Prosthetics). For instance, the sockets for prosthetic legs are made from soft and flexible silicon, which connects the residual limb to the prosthetic limb. Users report the silicon sockets make the prosthetics more comfortable. Carbon fiber also allows prosthetists to design lighter devices. These high-fidelity materials are expensive and hard to manufacture for custom parts, driving up the starting price of prosthetic limbs made from carbon fiber and silicon to $ 11,000.

In contrast, 3D printing technology enables rapid prototyping, customized parts manufacturing decreasing significantly production cost for specific parts (Mikołajewska et. al., 2014). This manufacturing method can be applied to prosthetic designs in order to improve customization for users while minimizing costs (Weller et. al., 2015).

The team has compared several low-cost 3D printed materials, including PLA, Ninjaflex, soft PLA, and combinations of these materials, by building prototypes via 3D printing. A combination of hard PLA and flexible Ninjaflex is the optimal material choice to create a low-cost prosthetic device that maintains functionality and can be 3D printed for easy and low-cost customization. Test blocks to design a secure interface between the two materials are shown in Figure 4. While the Ninjaflex enhances comfort of the product, regular PLA can tolerate higher stress without breaking which ensures the strength requirement for holding and grabbing objects will be met. Besides meeting the needs and purposes of product, the combined material also benefits the manufacturing process. As previous practices have demonstrated, the combination of materials allow manufacturing of complex mechanical joints in single 3D printing runs (Cali et.al., 2012). While concentrating on DFA (design for assembly), this feature of the material benefits the team to be able to reduce the number of parts within the design to enhance the durability and simplify the complexity of mechanical structure.

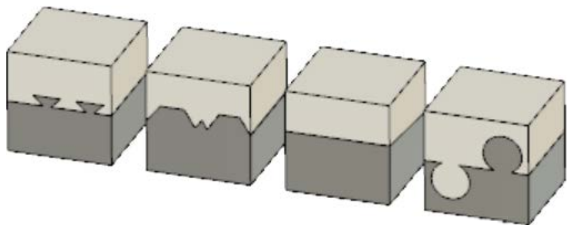


Figure 4: Multimaterial 3D printed blocks to test adhesion between hard PLA (White) and Ninjaflex (Black). Cube 4 adhered best under tension for multimaterial printing.

3. Technical Contributions

A. 2017-2018 Project Scope

The team predicts the hardware aspect of the platform will be most challenging to develop and has thus focused on design of prosthetic devices to be sold through the platform. Since the team plans to offer users a wide selection of devices from which to choose as well as help users transition from body powered to electrically powered devices, both a body powered prosthetic and a myoelectrically powered prosthetic are being developed.

B. Body Powered Finger Development

The finger prosthetic design will be actuated by movement of the wrist, knuckle, or other body powered means. Elimination of electrically powered means of actuation reduces cost and capitalized on natural muscle functions to maintain finger functionality.

i. Prosthetic design requires attention to material strength, allowable motion, ease of actuation, and fit

1. **Material strength:** Most hand prosthetics (In the range of $10,000-$20,000) are made of durable, high performance acrylics, plastics, carbon-fiber casings, and even titanium. The average life of these prosthetics is around 3-5 years, and corrective maintenance and selective replacement of worn parts can extend this even further. It is important to ensure that final product materials and design features meet these prosthetic requirements.
2. **Allowable motion:** Several iterations are needed while prototyping the fingers, to change the contours on the articulating parts such that they allow for optimal motion. The resting (non-actuated) position of the finger is typically in the fully-extended position, therefore it is important to ensure that the finger is well-aligned with the plane of the back-palm. During flexion, the finger must ideally close at a 180' angle, and it is crucial to ensure that there is a sufficiently large channel in the finger to allow

sliding over the knuckle component. Further, the 'tightness' of the joint should be adjusted (and kept slightly tighter than desired) to guarantee good control over each movement.

3. **Ease of actuation:** As stated by Dr. Richard, UCSF, most body-powered prosthetics use wrist flexion as the means of prosthetic hand actuation to grasp objects (Appendix A). This is often unintuitive and inconvenient, since it directs the hand away from the object it is trying to grasp. This results in the user having to tilt her shoulder, arm, or elbow at awkward angles, increasing the time required to perform a simple gripping action. The solution then would be to design an actuation mechanism that uses finger nub flex motion. This can be achieved by changing the point of attachment to the front or back of the palm.
4. **Fit:** In order to avoid discomfort the prosthesis must match the shape of the user's limb closely. As noted by interviewee Richard Nguyen, fitting is a complicated process and often takes several trips to the clinic to perfect. These designs will then be customized for each user through the automatic fitting process in the final platform product.

ii. Body-powered finger development with user testing allows for quick user-focused iteration

The close collaboration and constant constructive feedback from working directing with users through the prototyping process helps design products that are more likely to be well-received by the market. This has been proven to be successful in other case studies on prosthetic development as well (Swartz et.al., 2018). The team proceeded through an iterative fitting processes with finger amputees resulting in identification of functional requirements. The primary function these amputees desired was to improve their ability to grip cylindrical objects. This functionality should not sacrifice comfort because designing a comfortable prosthetic is crucial for prosthesis acceptance, and actuation must be smooth and intuitive. Tester feedback was incorporated into each design iteration to directly to meet his or her needs. Below is a description of the design strategy adopted by the team.

Prototype I: A string was attached to the end of the finger to a glove worn on the user's wrist. Ridges on the finger were designed to improve the grip (Figure 5).

Feedback: The user pointed out that there were several deficiencies with this initial prototype. He noted the inconvenience of wearing a glove used to secure the device to his hand. He also felt that despite the elastic benefits of using Ninjaflex, the design thickness required that he use a large amount of force to flex the finger. Additionally, the range of motion allowed by the design made it challenging to pick up a variety of object shapes using the finger (See Appendix C).

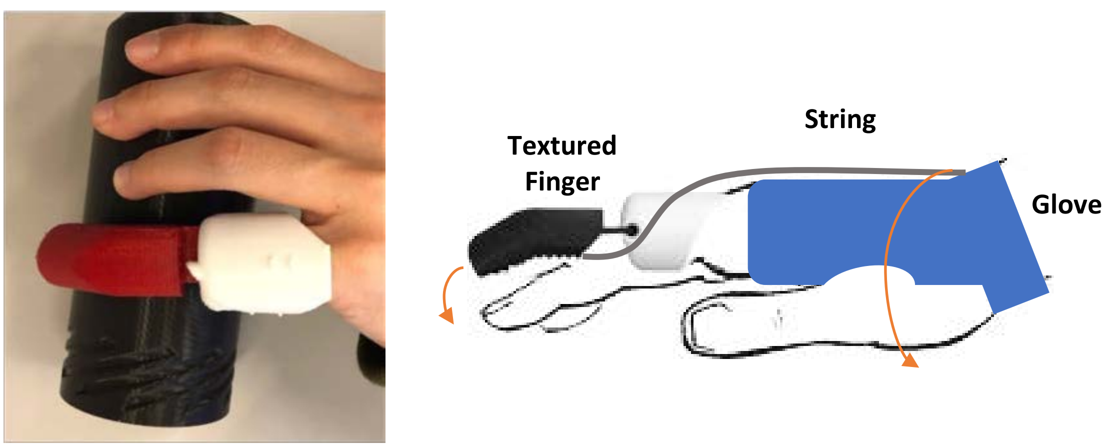
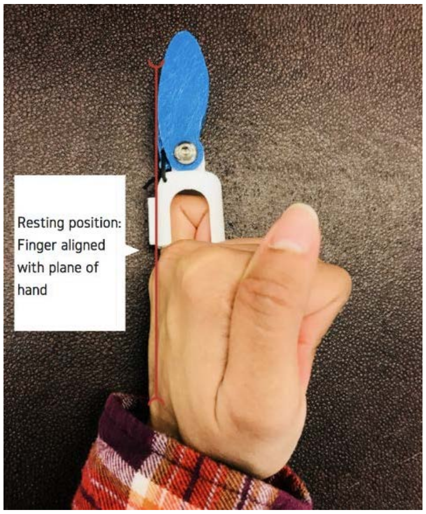


Figure 5: Prototype 1: A finger with grip features is attached to a glove. A tensioned string causes the finger to bend when the wrist is flexed.

Prototype II: A second improved prototype was built that used only a wristband rather than a glove, decreased the thickness of the spring feature, and adjusted the angle of the finger to be more versatile. This finger had the advantage of being light and not requiring a glove and was easy to assemble or disassemble (Figure 6).

Feedback: The friction from the string caused chafing along the ridge of the knuckle. In order to prevent this the guide for the string may be extended in further prototypes.



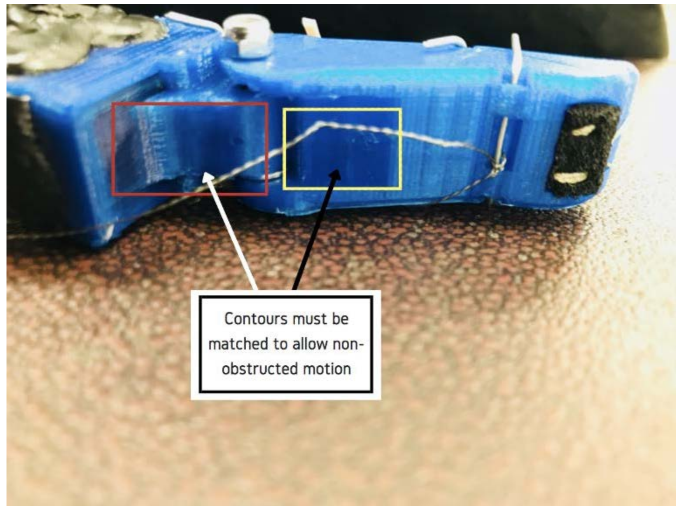


Figure 6: Prototype 2: A string attached to a wrist strap causes actuation. The finger is designed with an additional articulation point.

Prototype III: This prototype uses a knuckle cap to hold the finger in place and uses a 4-bar linkage mechanism directed mounted to the knuckle to rotate the finger.
Feedback: The team will conduct testing to see if this produces fingers with lower weight and better actuation (Figure 7).

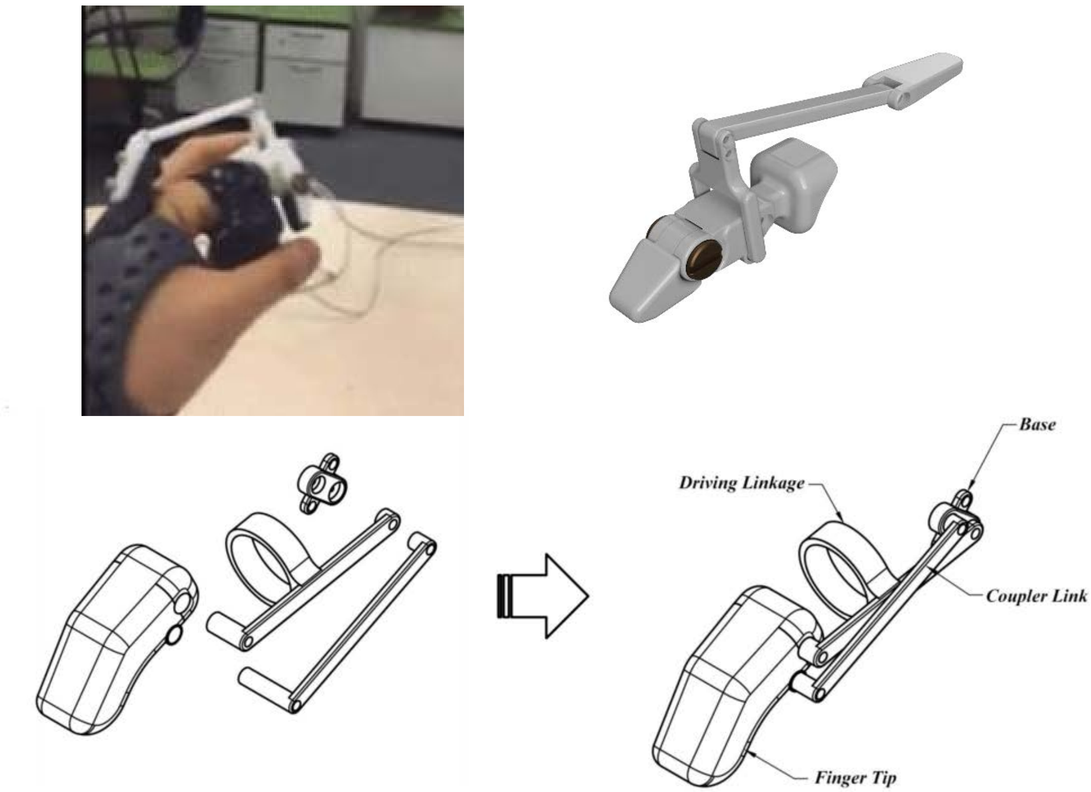


Figure 7: Prototype 3: A bar linkage system actuates the finger when the finger nub is moved.

C. Myoelectric Prosthetic Development

i. Myoelectric prosthetic development integrates muscle signal processing with haptic feedback

The implementation of the myoelectric function as part of the available prosthetic options on the Million Hands platform will require adhesion to the modular design model. The myoelectric prosthetic design implemented in this project uses electromyography (EMG) sensors to detect muscle contractions, a motor to mechanically actuate the hand prosthetic, and a microprocessor to link the myoelectric signals to motor commands (Figure 8). It also incorporates haptic feedback which uses force sensitive resistors at the fingers for detecting pressure and a system of vibrators on the subject's forearm that help the user feel the force of the grip.

Research on available prostheses by the Taylor and Francis group found that, although natural grasping largely relies on tactile feedback, there have been few attempts to integrate sensor feedback into prostheses (Antfolk et.al., 2014). Million Hands' myoelectric design integrates a simple feedback loop using a force sensor and vibration motor placed below the amputation site. The motor vibrates at greater speeds with greater force of grasping.

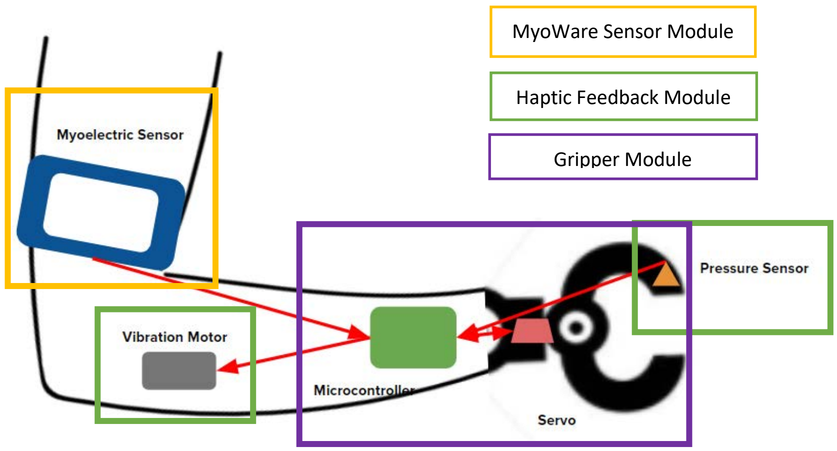


Figure 8: This diagram shows the flow of information from myoelectric sensor to microcontroller to servo to control the finger, and then back from finger's pressure sensor to microcontroller to vibrator on the forearm. The colored square outline design modules.

The three main subsystems comprising the myoelectric gripper hand design are the MyoWare signal processing algorithm, the prosthetic design and mechanical actuator, and the haptic feedback sensor and vibrator.

ii. Muscle signal processing in the time domain yields different signals depending on strength of muscle flexion

There is a need for a signal processing algorithm to convert myoelectric signals into motor commands. The signal processing algorithm used in the Million Hands myoelectric device is based on UC Davis Professor Sanjay Joshi's work on myoelectrics (Skavhaug et. al., 2015 and Lyons, 2013). Professor Joshi's lab has shown that two commands can be obtained from a single myoelectric sensor (Perez-Maldonado et.al., 2010). Through spectral analysis of the signal, Joshi found that subjects modulate the power of the 60-80 Hz and 110-130 Hz frequency bands of wrist muscles, therefore getting two different signals for different types of muscle flexion (Figure 9). Million Hands has applied this method to obtain resting, tight flexion, and light flexion muscle signals.

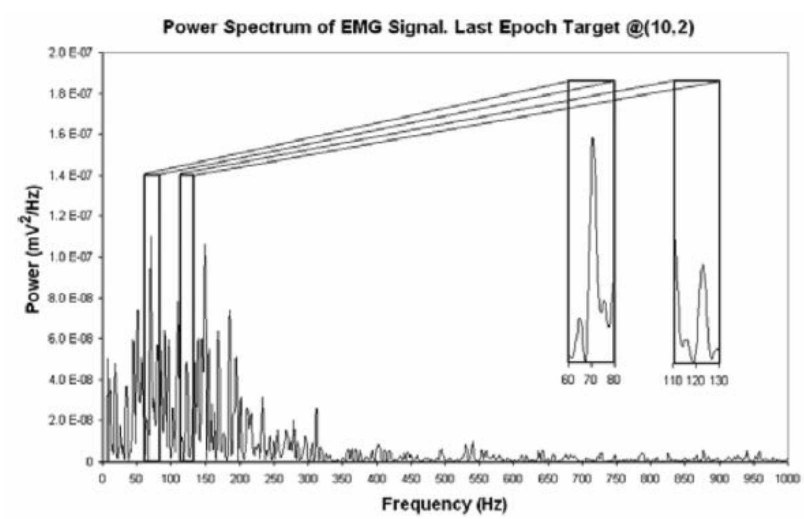


Figure 9: Adopted from Perez-Maldonado et al., 2010. Two distinct frequency bands are present during muscle contraction. These separate bands may enable differentiation of two different commands.

The data from the myoelectric sensors can be analyzed in both the time and frequency domain. For the current scope of the project, the MyoWare hand will have three states: “CLOSED”, “LIGHT GRIP”, and “TIGHT GRIP”. Processing data in the time domain and setting a threshold value around which the hand has a switch-on-off capacity is sufficient to lend the required control to the low-cost hand. The data in Figure 10 below shows the frequency peaks during resting, tight flexion, and light flexion. Light flexion has a peak in the 60-80Hz range

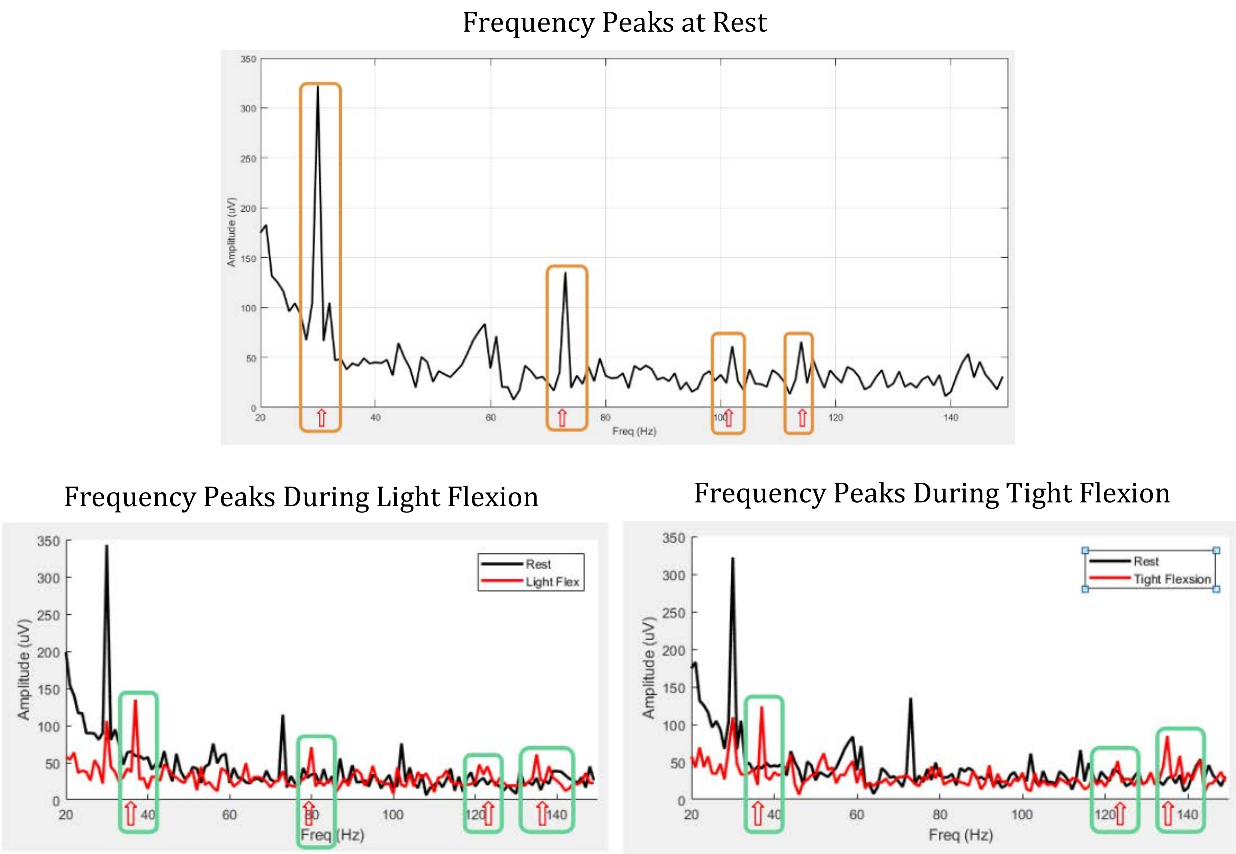


Figure 10: Frequency peaks are shown for 3 states: OPEN, TIGHT GRIP, and LIGHT GRIP

that is not present in the tight flexion spectrum. This allows for differentiation between two types of grips for the myoelectric hand.

The team is using the Adafruit Feather board with Bluetooth communication technology, nRF52, which has a small package size and can achieve the 300Hz sampling rate necessary to distinguish muscle signals. The Feather’s two-way Bluetooth communication will allow the team to implement a wireless myoelectric sensor in future designs.

iii. Device design allows for modular development of myoelectric prosthetic

The signals from the MyoWare sensor are used to control the articulation of a prosthetic hand designed by the Million Hands team. Currently, the muscle signals can product three levels of command, corresponding to the states of “CLOSED”, “LIGHT GRIP”, “TIGHT GRIP” for the prosthetic.

The prosthetic is designed as a proof-of-concept prototype for gripping. It is built from three modular components: the harness, the control package, and the gripper (Figure 8). The harness is designed to fit a person without an amputation or congenital hand difference, allowing the team to test and improve the design quickly. This harness will later be redesigned and customized for each user. The control package consists of the microcontrollers used to collect muscle signals, control the actuation and vibration motors, and collect force sensor data for haptic feedback. The gripper module contains the gripping features, servo motor to actuate these features, and the force sensor to detect grip strength.

Prototype 1 of this design (Figure 11) uses an external control package. The purpose of this prototype was to prove the gripping mechanism functioned and could be controlled by the muscle signals. This prototype did not contain the haptic feedback system, thereby preventing the tester from knowing the applied grip strength.

Prototype 2 (Figure 12) uses a more streamlined design that includes a mounted control package as well as a haptic feedback loop. This design allows the user to have a compact device that detects grip strength. Prototype 2 is also designed to provide a comfortable, intuitive prosthetic experience by using ergonomic features, reducing material use, and using soft materials for fastening.

Alongside this algorithm, the team is working on integration of actuators, haptic feedback sensors and a mechanical design for the hand that allows for mounting of all electronics while maintaining comfort for the user.

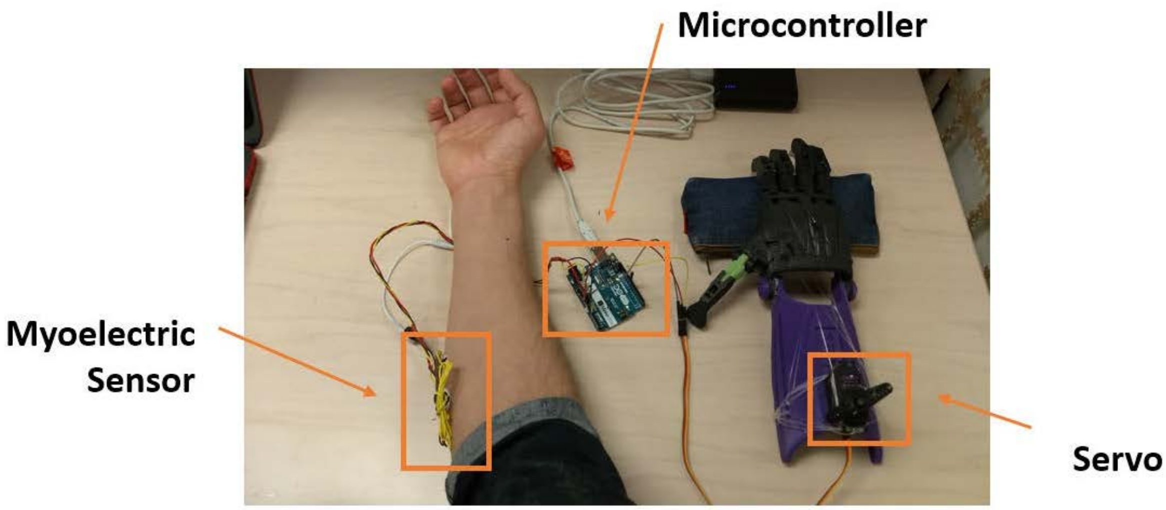


Figure 11: Prototype 1: Modules are separated for testing and development ease.

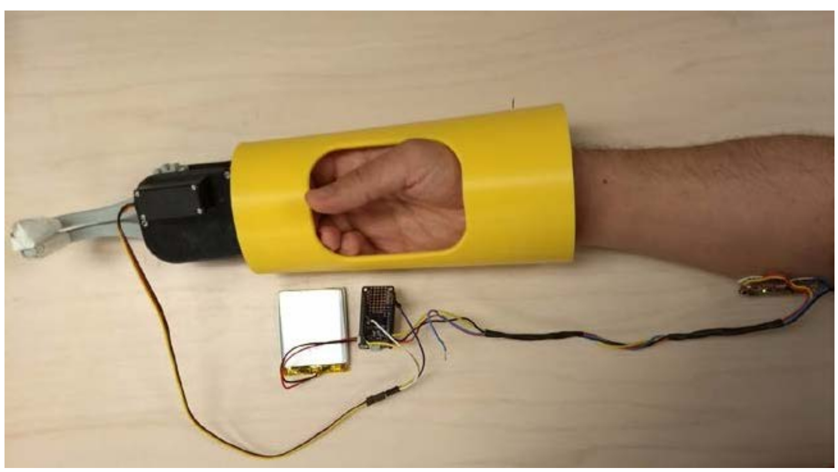


Figure 12: Prototype 2: Gripper design. Assembled package not shown.

iv. Simple haptic feedback loop simulates tactile feedback

A sensor – motor system is integrated into the myoelectric hand design to improve sensor stimulation for the user. A force sensor mounted on the gripper of the myoelectric hand detects the grip force exerted on an object. The force sensor data is used to modulate a coin vibration motor mounted on the inside of the prosthetic harness such that it touches the user's skin (Figure 13). Vibration has been proven to be the universally preferred method of mechanical haptic feedback relative to electrical stimulation (Shannon, 1976). Increased force increases the speed, and perceived intensity, of the motor. The haptic feedback intends to improve the user's control over their grip force. In combination with the signal processing algorithm which can differentiate between tight and light flexion, the haptic feedback will tell the user when to ease or tighten their forearm flexion to control prosthetic actuation.

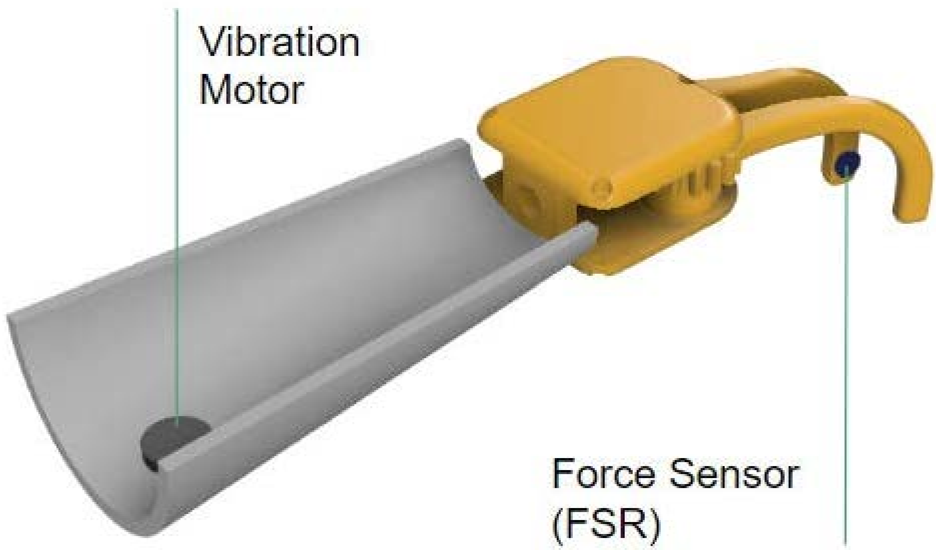


Figure 13: Haptic feedback system shown on gripper model

5. Conclusion

Million Hands' employment of human design methods to define goals has established a solid foundation from which an impactful product can be developed. The platform will make prosthetics easily customizable and highly functional at lower cost than current products. Though the team has made significant progress in design prosthetics to be made available on the Million Hands platform, more research is required in the areas of automatic sizing of the designs and website development. The body-powered finger prosthetic and myoelectric hand prosthetic can also benefit from additional work to improve grip control and aesthetic appearance. As this project continues, it is also critical to continue to work with industry experts and users to ensure the Million Hands platform meets the needs of those with upper limb amputations and congenital differences.

6. Acknowledgements

The Million Hands team would like to acknowledge the guidance of project advisors Dr. Alice Agogino, Dr. Grace O'Connell, and Daniel Lim. The team would also like to thank UC Davis Professor Joshi for advising myoelectric signal processing development and UC Berkeley's Robert Matthew for prototype development assistance. Finally, the project would not have been possible without the generous support of Dennis Chan and the Million Hands: Prosthetic Hands for Children through an Open Source Platform, 3D Printers and Sensors CITRIS Grant.

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8. Appendix
A. Appendix A: Transcript of Interview with Richard Nguyen

Interviewee: Richard Nguyen
Interviewers: Jose Ramirez, Aashish Bhardwaj, Aastha Shah

Date: February 6, 2018

Location: richard.Nguyen2@ucsf.edu

Background: Richard Nguyen is a clinical manager at UCSF's orthopedic and prosthetic center. He manages a team of prosthetists who design custom sockets for body powered prosthesis. He has an extensive background in physiology and has worked with several different custom prosthetic groups including Limbforge. By working with customers every day he has familiarized himself with the process of obtaining prosthetics and has become an expert on user needs. He agreed to sit down with us to talk about insights he had on user needs.

Key Takeaways:

- In general prosthetics are cumbersome and burdensome to use, if the user can get along without it they will. Therefore, prosthetics have to be easy to use, have minimal footprint, and make a big impact on the users lives
- A large portion of the expense comes from the process of getting the prosthetic rather than just the device itself
- In the United States, users expect a lot out of their devices, won't be satisfied with incremental improvements
- 3D printing has problems for actual prosthetic use, more suited for prototyping
- 3D printing layers

B. Appendix B: Interview with Matthew Garibaldi

Interviewee: Matthew Garibaldi
Interviewers: Sina Dabiri, Jose Ramirez

Date: February 6, 2018

Location: richard.Nguyen2@ucsf.edu

Key Takeaways

- The main portion of the cost of the prosthetics is due to the clinicians being able to bill the insurance only one time for the 15+ visits the patient makes to get one prosthetic (Bundled payment).
  - Don't focus on making low-cost prosthetic
  - Having a prosthetic that needs multiple replacement will delay care for couple of months at a time. Focus on the quality to be one year durability.
  - Do not decrease cost by focusing on 3D printing at the expense of quality and functionality.
  - Make something that works within the current health care system. Think how it fits in the whole system. Prosthetist still use the manual measurement. Need to upgrade such that patient comes in get their normal hand 3D scanned. Then 3D scan is converted to CAD design and prosthetic features are added and then printed. As the person grows and changes it is easy to change the size of for example the socket and harness. The doctor can keep track of each patients hand changes.
- Female vs. Male preferences: young females want an anthropomorphic aesthetically looking hand, whereas males want a mechanically looking robotic hand.
- Comments on the glove and finger design for Curtis: there are currently couple of companies making finger designs: 1- Naked Prosthetics (http://www.npdevices.com/) 2- x-fingers (http://www.x-finger.com/x-finger-models.html)
- Lack of sockets in market
  - Limb Innovation has good modular and customizable sockets.
- FDA: myoelectric hands are class II and the passive ones are class I
- Interview as many Prosthetist across the country. He will send us contacts to talk to across the country and learn what prosthetics are missing in the market.
- An anthropomorphic aesthetically pretty hand for females that is based on simple myoelectric is missing in market.

C. Appendix C: Transcript of Interview with Curtis

Interviewee: Curtis
Interviewer: Jacquie, Sina, Jose, Aashish

Date: January 20 2018

Location: Citris Invention Lab

Background: Curtis suffered from an acute case of toxic shock syndrome. The affliction required the amputation of his fingers. As a fellow maker, he has been working with the Citris invention lab to develop novel finger prosthetic fingers. His regular visits to the lab allowed the Millions Hand team to test their designs and iteratively improve them with his suggestions. In addition, his interview provided invaluable insights into the everyday needs of finger amputees.

Insights:

- Fingers have to be easy to actuate, even moderate difficulty in actuation mechanism makes it a difficult use
- Fit of the socket of the finger is paramount to design success
- The main problem the fingers are trying to solve is gripping cylindrical things.
- Angle of actuation and length of the finger are important for determining the functionality of the finger
- Gloves have to be lightweight and breathable to prevent discomfort.

D. Appendix D: Bill of Materials for Myoelectric Prototype

Part Number	Part Name	Description	Manufacturer	MPN	Quantity	Unit Cost (USD)	Ext. Cost (USD)	Notes
1	Myoware Sensor	Muscle sensor	Adafruit	2699	1	$37.95	$37.95	Link
2	Muscle Sensor Surface EMG Electrodes	Electrodes	Covidien	H124SG	3	$0.83	$2.48	Link
3	Coin Mobile Phone Vibration Motor	DC3V/0.1A 1.5V/0.05A 10x2.7mm	Uxcell	a14061100ux0057	1	$0.70	$0.70	Link
4	Feather	Microcontroller	Adafruit	nRF52	1	$24.95	$24.95	Link
5	Force Sensor	Force Sensitive Resistor, Small	Sparkfun	SEN-09673 ROHS	1	$5.95	$5.95	Link
6	3D printed Gripper Hand	Prosthetic Hand	Million Hands		1	$50.00	$50.00	Estimated Price
7	USB-A to Micro-USB Cord	Cable 1 ft	Amazon		1	$4.79	$4.79	Link
						TOTAL COST	$126.81	