Partial Hand Prosthetic: Experimental Team

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Project Overview

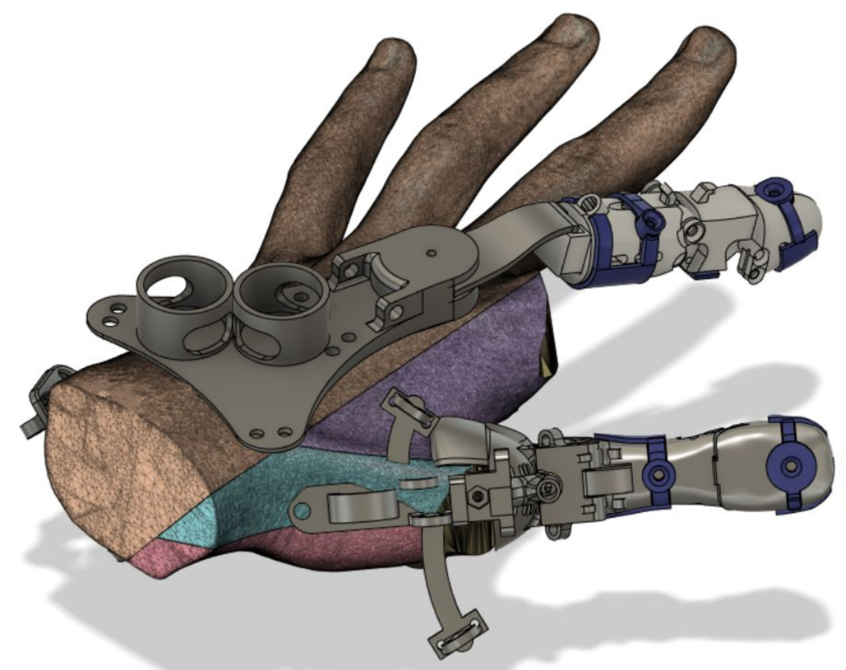
Most partial hand prosthetics made today are non-functional, providing aesthetics rather than dexterity. Prosthetics that provide dexterity are only available for either full hand amputations, or for finger amputations with a remaining proximal phalanx. The purpose of this project is to fill that gap. This MQP worked in conjunction with the Partial Hand Prosthetic: Core Function MQP to expand upon last year's Partial Hand Prosthetic MQP to integrate haptic feedback systems, allow for variable compression, and enhance thumb control. To continue to improve the partial hand prosthetic design we created a web interface allowing customization of the prosthetic behavior, sensors determining compression on the prosthetic fingers to control vibro haptic feedback to the user, a harness which the user can control the tightness of, and increased thumb positioning accuracy via an array of hall effect sensors. Through qualitative and quantitative testing, the device has demonstrated its ability to give feedback while restoring dexterity.

Background and Goals

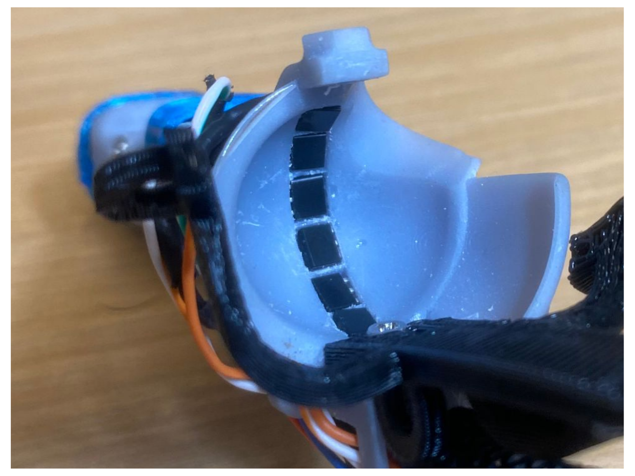
Around more than 61,000 partial hand or finger amputations occur every year in the United States. Most of the prosthetics available to these amputees are purely cosmetic and do not restore dexterity. Additionally, around 50% of amputees reject prosthetics due to the prosthetic not providing meaningful feedback or a tactile sensation. The amputee's ability to form a mind body connection with a prosthetic is of similar importance to dexterity restoration. In this regard,various ways of sensing touch and communicating it to the amputee are being developed. This project served to expand upon a previous project by accomplishing the following goals:

- Thumb with positioning accuracy within <1 mm at the thumb tip throughout the thumb's full range of motion, with 1.5 seconds to travel full range of motion in one direction
- Actively limit torque to 90% or less of the thumb servo's experimentally determined stall torque
- Harness with Variable compression system actively responds to force on finger pad sensors and motor forces with maximum compression of at least 5lbs at back of hand
- Localized haptic feedback with 5 channels, one per finger segment (3 on index 2 on thumb), communicated via haptic feedback on vibro-haptic motors mounted on the back of hand, embedded in the sleeve. User can select between at least 3 vibro haptic patterns and intensity.
- Wrist module mass no more than 200g, size no more than 85mmx62mmx25mm
- Additions to core-team's prosthetic mass no more than 10g each on index and thumb, 50g hand harness
- Receive, integrate, and report on feedback from the device user on: ease of use, comfort, and performance of hardware, performance of software.
- Create web interface for adjusting settings (input sensitivity, movement speed/acceleration, compression harness gains) and visualizing sensor/actuator data at faster than 10 hz (thumb servo positioning, current draw, force readings, battery level)

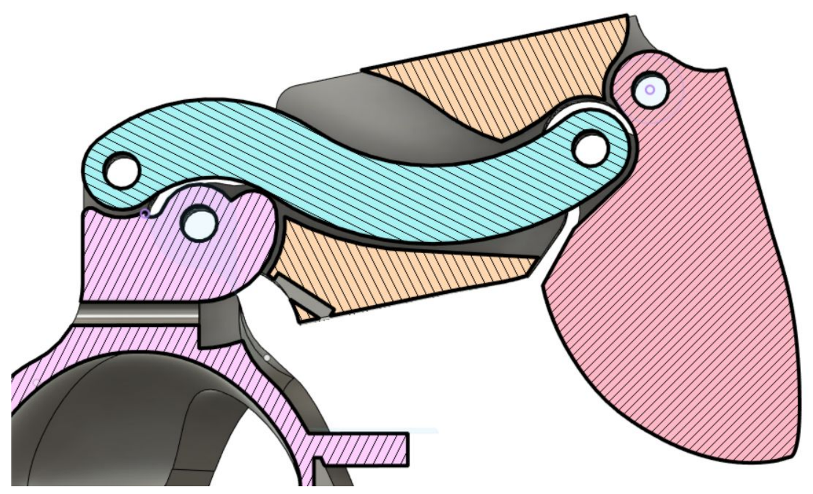
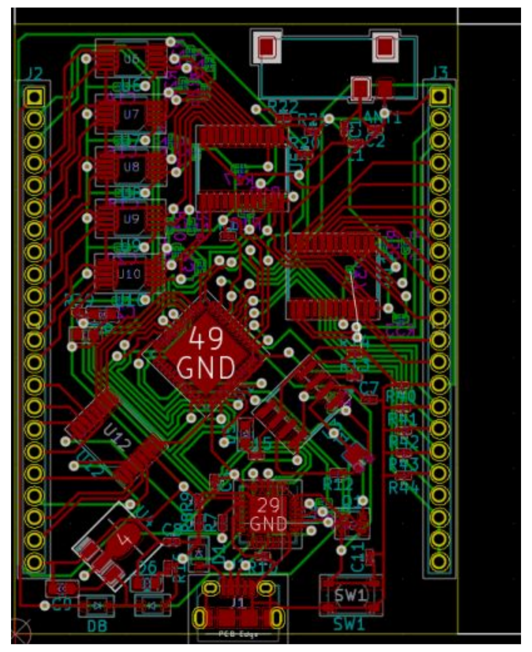
Design




A main concern for the prosthetic was stability. Using a designed with four thermoformed parts the harness was able to be shaped exactly to the contours of the patient's hand. The harness has 4 cables running through it, allowing the user to tighten and loosen the harness as needed, depending on activity and comfort. This allows the device to be tightened when under heavy use then loosened for comfort.

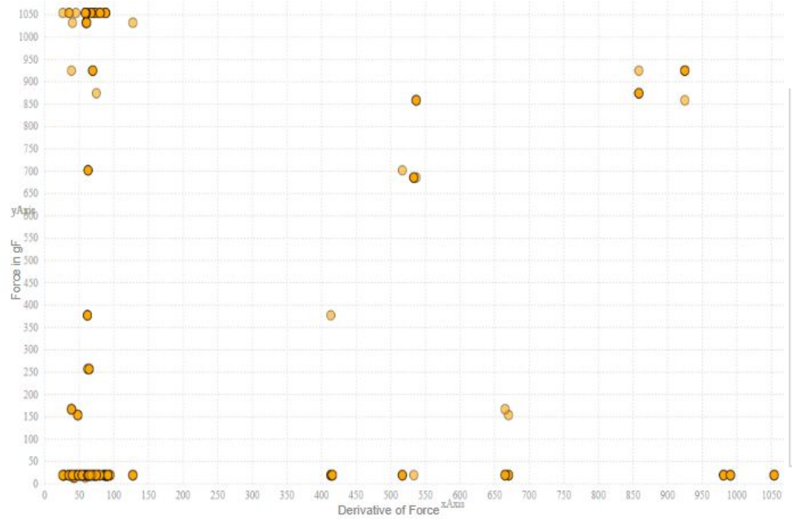


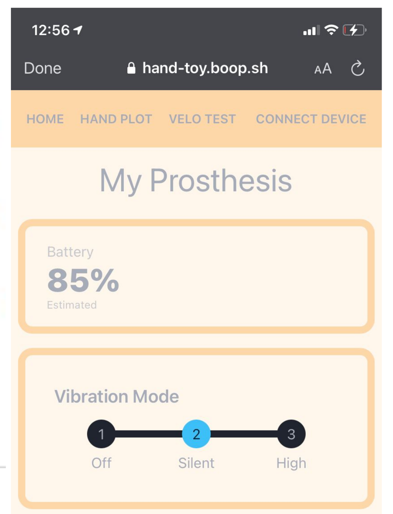

To track the position of the patient's bone fragment we used placed an array of magnetized silicon over hall effect sensors (shown left). To detect touch on the fingers we created small, force sensitive sensors from layers of velostat and copper to act as inputs for the vibro haptic motors that reside at the back of the hand (under the back plate).

The fingers were actuated with 4 bar linkages (shown left) which were generated to mimic natural motion. These linkages are actuated using boudin cables. Improvements over the previous year's wrist module were made by using a PCB (shown right) to condense our circuit to a smaller volume.

Analysis



In order to provide varied haptic feedback we needed to classify the type of contact on the finger's force sensors. To do this we ran a clustering algorithm on the force and its first derivative. The magnetic dots were placed in between each hall effect sensor. The response shown demonstrates how the pressing of one of these dots is detected by the surrounding sensors. The web page displays information and settings that can be changed by the user.

Discussion

The final version of the prosthetic includes a vibrohaptic system, a user adjustable compression harness, a magnetic sensor that allows for increased thumb positioning accuracy, and a web based UI. The vibrohaptic system is divided into two parts: five force sensors with two on the thumb and three on the index finger and five small coin vibration motors that output various vibration patterns depending on the fluxuations in the force data. The velostat sensors were selected over other options due to their ability to be made in various shapes and their thin profile, and the TPU caps over them increase durability while allowing force to still be transferred. The user adjusted compression harness allows for increased user control over tightness and comfort, as well as making doning the device easy. The magnetic thumb position sensor allows for precise tracking of the patient's residual bone fragment. This then allows for the actuation of the thumb to closely track the position of the fragment, rather than moving at a set speed from buttons. The web UI allows for the user to see details of the device, have data visualized, and select settings for the vibrohaptic feedback and thumb control.

Future Work

While the user adjusted variable compression harness secures the device, an automatic variable compression that responds to the velostat force sensors or the force of the thumb motor would create a better user experience by allowing the harness to be automatically tightened during use in response to greater forces acting on the fingers. Additional information can be displayed to the user over the web interface, such as statistics about usage like grips per day. A higher resolution vibrohaptic system would provide the user more detailed haptic feedback. This could either be done by increasing the number of sensor-motor pairs, or by increasing the number of types of touches the clustering algorithm can discern between.

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