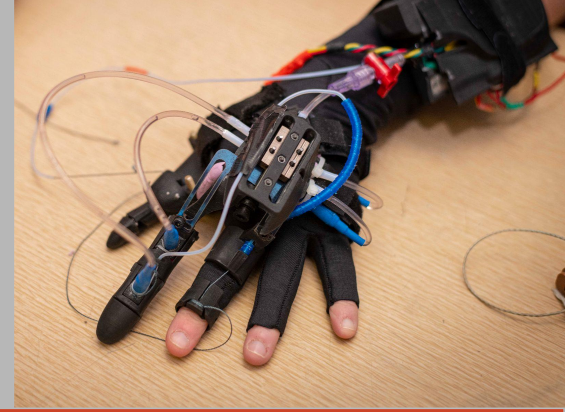
Partial Hand Prosthetic



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Abstract

The purpose of this MQP was to develop a partial hand prosthetic for a patient with an amputation at the metacarpophalangeal joint of the index finger and thumb. There are no commercially available prosthetics for this specific injury and so this MQP tackles this gap in prosthetic technology. The resulting solution consists of a two degree of freedom passively actuated index finger, one degree of freedom sensor driven thumb, solenoid locking system, and passive variable compression bladder. Both qualitative and quantitative testing has demonstrated that this device restores the pinching capabilities of the patient.

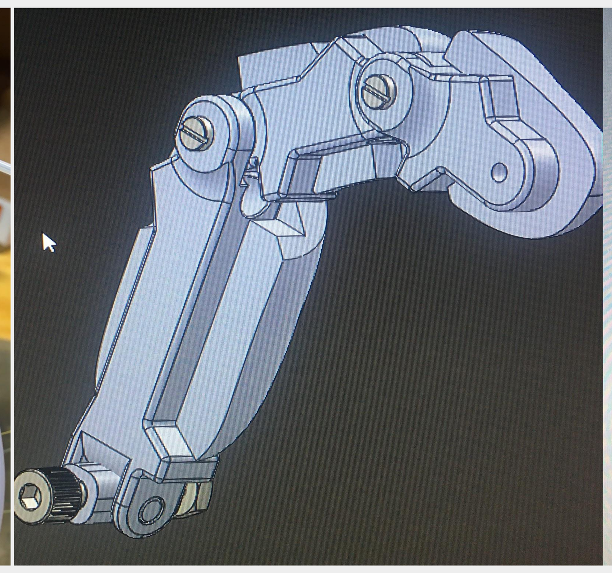
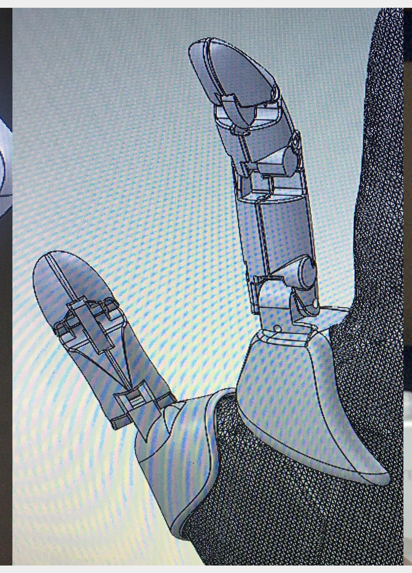
Background

Partial Hand Prosthetics are an unexplored section of the Prosthetics market. Partial hand and finger amputations occur at a rate of approximately 61K each year in the United States. The amputation of a thumb in particular results in the loss of approximately 40-50% of hand functions. Up until now the only option for a person with an amputation on the hand above the metacarpal is a silicone cosmetic finger, which serves no function and is often reported to get in the way.

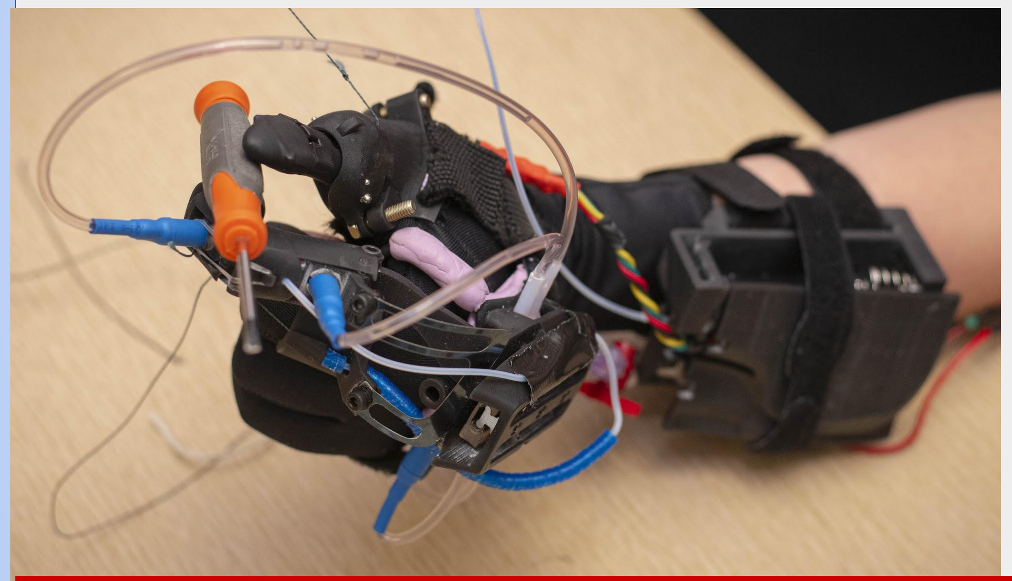
Objectives

Objective	Outcome
Two degree of freedom index finger	Completed
2s for full actuation	2.96s for full actuation, however this project is ongoing and methods to increase the efficiency of this digit will be addressed
750 grasping cycles per charge	Completed: 983 grasping cycles/charge
Breaking point of 44N/m² at finger tip	Completed: 3.9E7 N/m²
Weight of index finger: Goal 75g	88.5g; while this objective was not achieved, the user reported being happy with the weight and as it is only a difference of 13.5g we are happy with this result
Weight of thumb: Goal 50g	Completed: 31.9g
Weight of wrist module: Goal 250g	Completed: 110.9g
Easy to don and doff	Took ~10 minutes and no consistency with thumb and sensor placement, however this project is on-going and the team has plans to improve upon this
Intuitive control via embedded sensors	Completed
Grip strength of 13N at actuated fingers	2.7N at actuated fingers, however this project is on-going and the team has plans to improve upon this
Easily rechargeable	Completed: exchangeable batteries and charging port

Design and Analysis


This is prototype two, the first design were we moved to bowden cable style of actuation. This allowed us to control each joint individually, allowing for fine control of each joint. This prototype served as an excellent proof of concept for multi DOF prosthetic fingers.

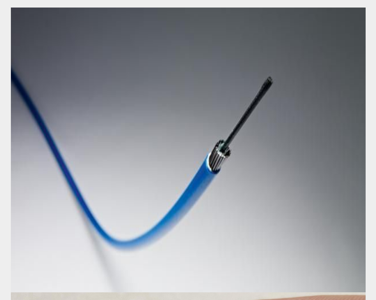


The third prototype featured a simpler design with drastically fewer parts. This prototype was our first attempt at a real working prototype for out patient. To make it more useable we reduced the degrees of freedom for the index finger and thumb making the distal phalanges move in conjunction with the Proximal Phalanges using a linkage. The index finger also featured a built in tensioning mechanism that allowed the bowden cable tension to be adjusted easily by the user. Overall this design failed to be functional because the harness did not consider that the patients MCP joint still moved on her hand.

The fourth prototype set out on the mission of fixing the harness issue that was pervasive in V3. We developed a general interface utilizing the hands natural geometry and a new patent pending variable compression harness that adjusts its tightness according to the loads applied during use. This allows for a comfortable and tight when it as to be harness design that stays ridegly attached to our patients hand even when she moves or grips. This design also has many improvements to the index finger and thumb to increase strength and flexibility as well as reduce force of actuation.

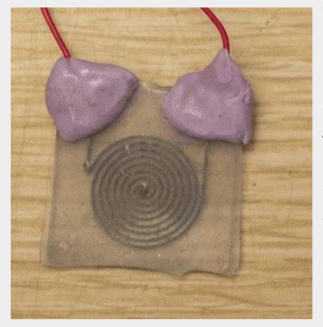
Actuation

Index Finger



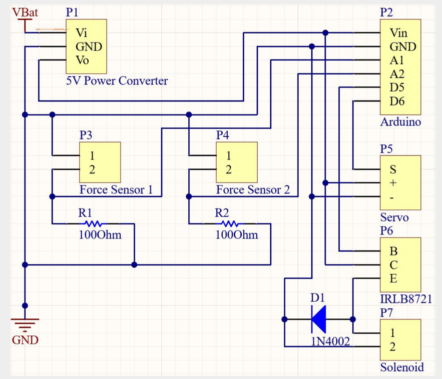

The index finger itself is a novel two degrees of freedom passively actuated design. Using a spring steel pusher attached to a linear slider we are able to move the MCP joint of the prosthetic in conjunction with her middle finger. For the second degree of freedom we use a custom bowden cable to allow us to jump over her MCP joint and transfer motion from her middle fingers PIP to the PIP of the device.

Thumb



The motorized thumb is powered by two liquid metal sensors. When pressure is applied to sensor 1 the thumb moves forwards, when pressure is applied to sensor 2 the thumb moves backwards. The thumb is powered by a continuous rotation servo that is able to fully close the finger in 0.046s. There is also a solenoid zip tie rlocking system implemented in the circuit. This solenoid is able to lock the thumb in place so that when it is under load it can maintain its position. This allows us to both use less power for the system and to use a smaller motor, keeping the size and weight of the system down. The entire electrical system is housed in an external wrist module with a removable and rechargeable battery.

System Logic



The code for this device is very simple as it is only interfacing between a motor, solenoid, and two pressure sensors. If the pressure in either sensor is greater than 1 it indicates that the motor should move in the specified direction. As the pressure increases the speed of the motor also increases. If both sensors experience pressure then the sensor with the larger value is taken and the thumb will move in that direction. If there is no pressure on either of the sensors, the solenoid is activated and locks the thumb in place by interlocking the teeth of two zip ties.

Discussion

After going through a swift process of iterative design moving through countless prototypes with 4 main redesigned we have achieved an initial functional product for our end user. The system features a passively actuated index finger as well as a passive force reactive harness. The thumb is controlled actively by two embedded sensors which sense the movement of residual bones structure left over from our patients surgery. We are hoping this research can open a new dialogue between prosthetists and surgeons about the usefulness of leaving specific features to be used for prosthetic control.

Future Work

In future iterations of the design we will improve the passive force activated compression system in the harness. We also will have to look into improving the ease of use in terms of actuation forces for the index fingers PIP joint and active sensing. This will require another major redesign including improved sensors, improved sensor placement, and an integrated glove so that the device can be doned and doffed quickly and easily. Some other measures must be taken to improve the middle finger actuation rings as well.

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