Prosthetic Thumb

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Abstract

- Patient suffered a severe infection resulting in the amputation of dominant hand thumb, pointer finger, and middle finger as well as loss of function of his ring finger
- Patient is now unable to complete simple tasks, resulting in the inability to find a job
- Design and create a low cost prosthetic thumb to act in opposition to the currently existing pinky to increase hand function for patient
- Successfully created working prototype controlled by wrist flexion

Background

- Amputations from infections account for 38 amputations in the US per day
  - Individually designed prosthetics often necessary due to variability in injury extent and location
- Cost of singularly produced prosthetic device is expensive
  - A technologically advanced prosthetic can cost $50,000
  - "Budget" prosthetic can cost $5,500-$9,500
  - Poorly insured and uninsured patients lack cost effective solution.

Figure 1: Image of Patient's Hand

Problem

- Patient is a low income individual who lost most function in dominant hand due to infection. Current prosthetics are far too expensive without insurance, and amputation is unique.
- Patient suffered the amputation of dominant hand thumb, pointer finger, middle finger, and portion of the palm due to severe infection
  - Ring finger is non-functional
  - Pinky finger has 10 degrees of flexion at metacarpophalangeal joint
  - Sensitivity and pain at location of digit amputation
- Patient has 20-30 degrees of flexion/extension at the wrist
- Skin graft from palm to ⅔ way up the forearm resulting in superficial sensitivity

Figure 2: Image of current temporary prosthetic.

Design Criteria

- Prosthetic must:
  - Work in opposition to the existing pinky
  - Stabilize and hold objects that range in size from 1-10 cm
  - Lift and hold objects up to 2.5 kg
  - Provide stability to perform fine motor skills such as writing
  - Allow for comfortable wear of up to 8 hours at a time
  - Perform skills needed for employment on an assembly line
    - Allow for future modifications based on specific work tasks desired
  - Have minimal cost and be accessible to low income/ uninsured amputees

Figure 3: Pencil holder attachment

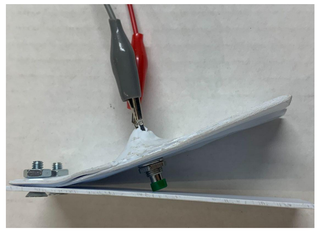

Figure 4: Wedge encasing for button

Materials & Methods

Materials:

- ABS printed thumb mechanism
- Polystyrene thermoformed plastic
- Arduino Nano and motor driver
- Battery powered button and linear actuator

Figure 5: Linear Actuator

Figure 6: Arduino Nano

Figure 7: Push-Button Switch

Figure 8: Motor Driver

Methods:

- Thumb mechanism designed in Solidworks
- Thermoformed cuff with velcro attachments
- Motion driven through a cable tension system utilizing an elastic and a cord
- Printed with 60% infill ABS plastic
- Finger pieces with Flex Seal applied for grip
- Moves with a 50mm stroke motor
  - Powered by a motor driver/Arduino circuit.

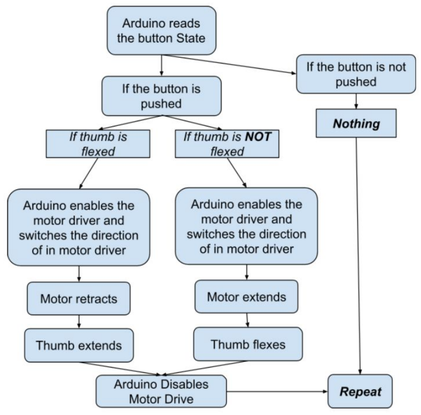

Figure 9: Flowchart of the code implementation

Testing and Results

- Clinical Testing:
  - Patient was asked pick up and move objects of varying weights and sizes
  - This testing highlighted:
    - Functionality of the design
    - Maximum size and weight holding capabilities
    - Patient comfort level
- Quantitative Testing:
  - Force output test
    - Average Max Output: 8 N
  - Range of motion test:
    - Grasp range is 1 - 10 cm
    - 20 degrees of flexion measured in ImageJ
  - Reaction time test:
    - Time from flex sensor deployment to full flexion of thumb
    - Reaction time = 1.08 seconds
    - Compared data to the desired reaction time of 1 second

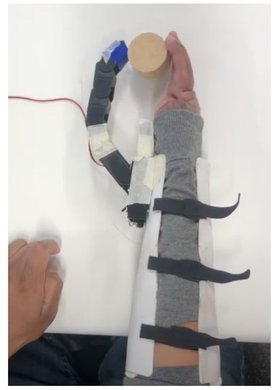

Figure 10: Picture of patient successfully picking up a cylindrical object

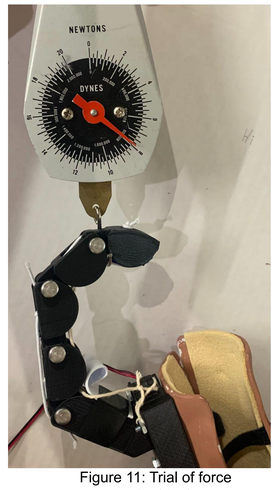

Figure 11: Trial of force output test

Fabrication

Mechanism:

- The thumb mechanism moves by an upward linear motion supplying 10 cm range of motion with 20 degrees of flexion
- Flex Seal, a gripping material, used on mechanism for grasping

3D Printing:

- Designed on Solidworks and 3D printed using ABS Plastic

Cuff:

- Thermoformed to mold of patient's arm using ⅛" polystyrene
- Cuff painted to match the patient's skin tone

Attachment:

- 3D printed mechanical thumb bolted to the cuff
- Cuff attached to patient's forearm using velcro
- Cord and elastic tied at various points to obtain desired motion

Circuit:

- Button attached to circuit system to be hit using patient's inner arm
- Inputs signal to Arduino Nano microcontroller
- Extension and retraction of linear motor dependant on the press of the button

Final Design

- Final prosthetic manufactured based on the design criteria
- Cuff custom-made to the size of the patient's arm attached tightly by velcro straps
- Cuff is lined with cushion material to increase patient comfort
- Motor and mechanical thumb are bolted onto the cuff
- Button is encased in a wedge piece to provide more surface to activate
- Additional attachment for holding writing utensils

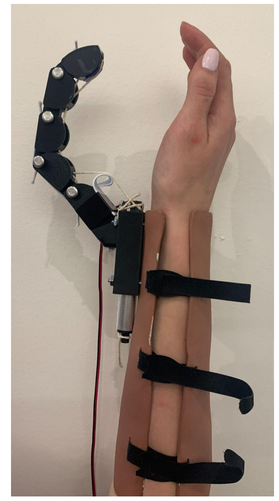

Figure 12: Image of the thumb design

Figure 13: Inner cuff design

Future Work

- Reprint final design using skin colored ABS plastic
- Finish a user manual
- Ship product to the client

Acknowledgements & References

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