Prosthetic Hand

Emmalina Groves, Danielle Lefko, Stephanie Silin, Karen Scharlau

Client: Shirley Katz, OT

Advisor: Mitchell Tyler– Biomedical Engineering Department

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 $70,000
  - "Budget" prosthetic can cost $5,500-$9,500
  - Poorly insured and uninsured patients lack cost effective solution.

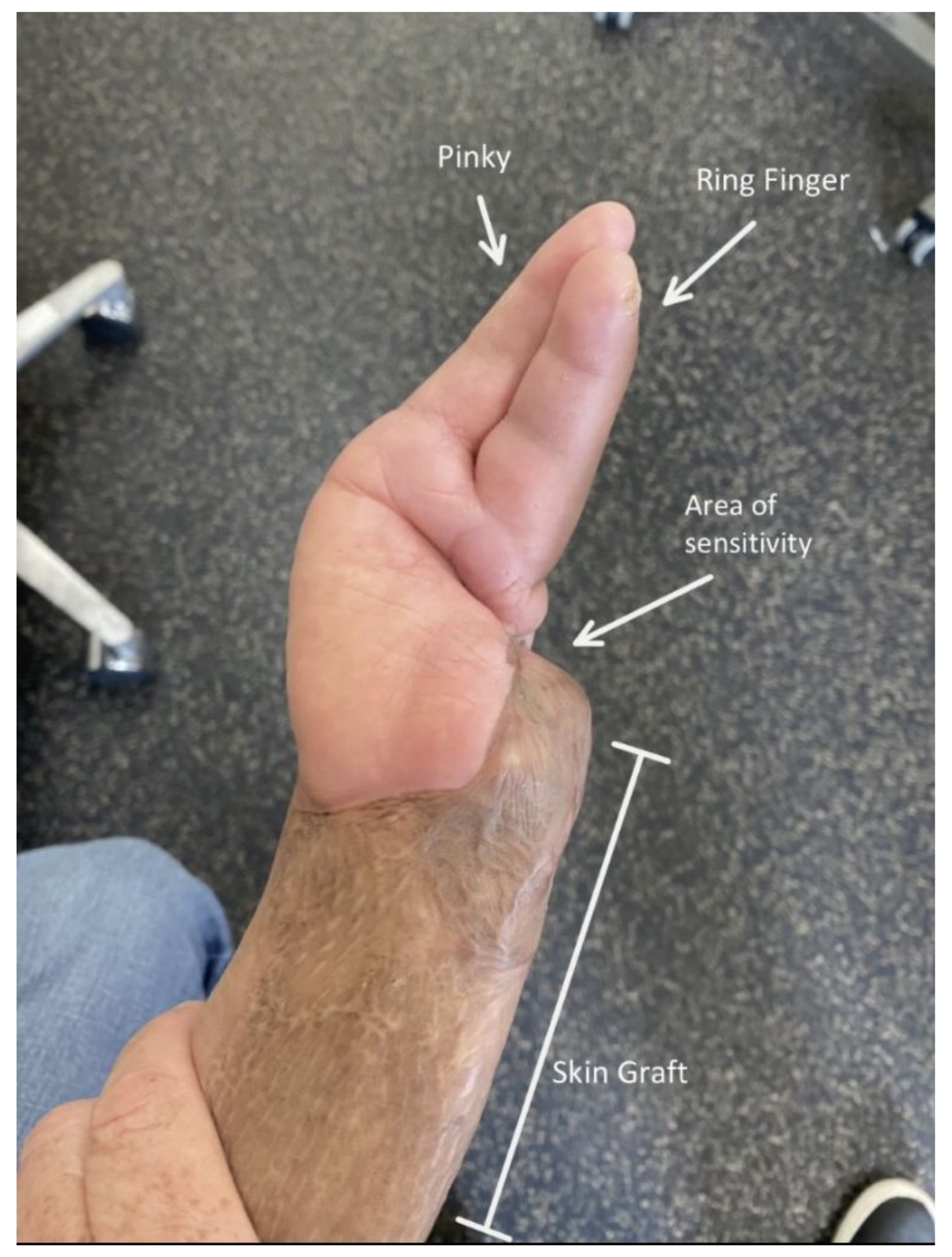

Figure 1: Image of Patient's Hand

Problem

- Patient is a low income individual who has lost most function in his dominant hand due to an infection. Current prosthetics are far too expensive without insurance, and the extent of the injury is unique.
- Patient suffered the amputation of necrotic 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 at location of finger 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 Skin Graft and Area of Amputation

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

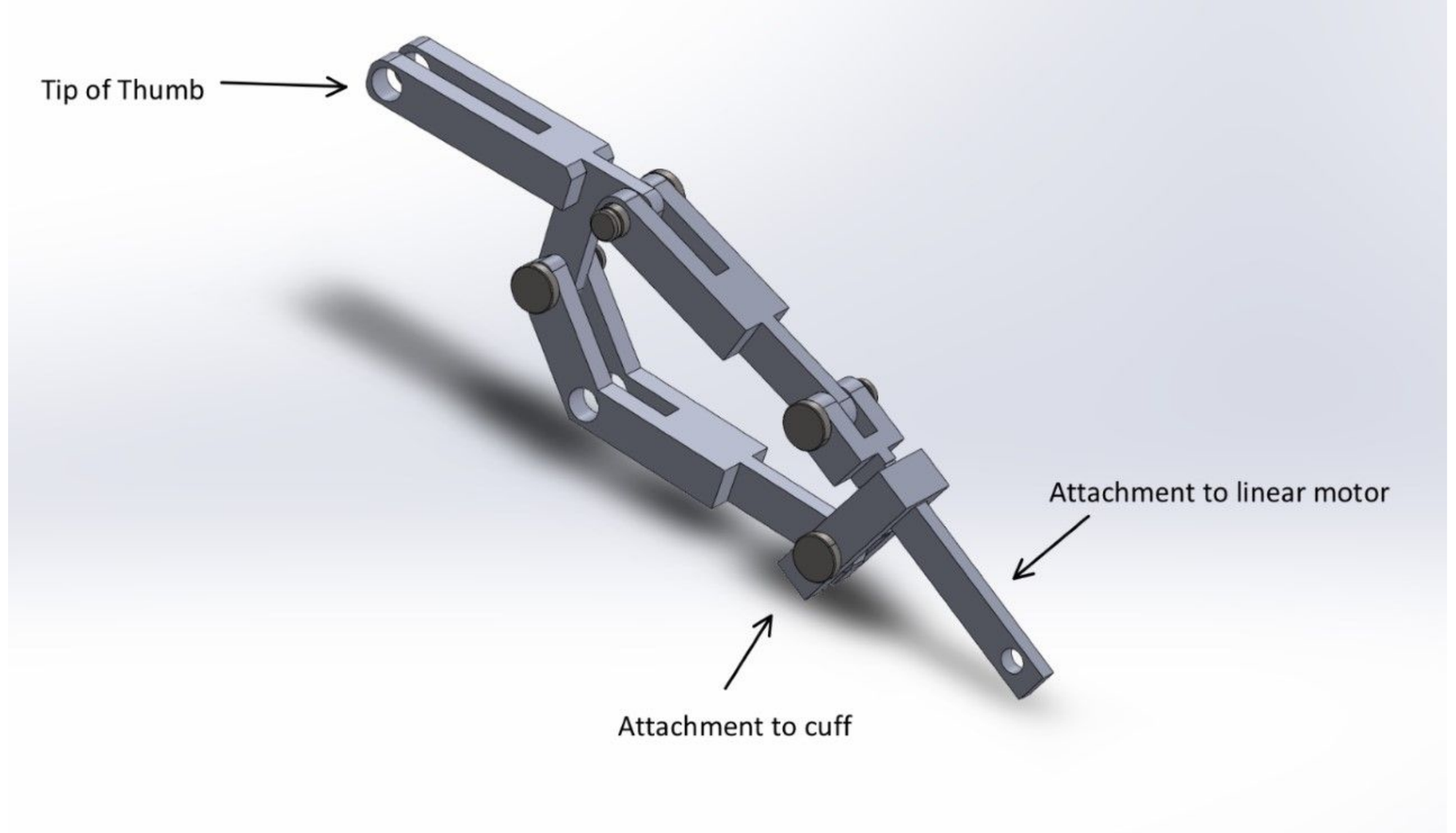

Figure 3: Mechanical Thumb Solidworks Design

Materials & Methods

Materials:

- ABS printed thumb mechanism
- Polystyrene thermoformed plastic
- Flex Seal
- Stainless Steel clevis pins
- Arduino and Motor Driver
- Battery powered Flex Sensor and Linear Actuator Motor

Figure 4: Linear Actuator

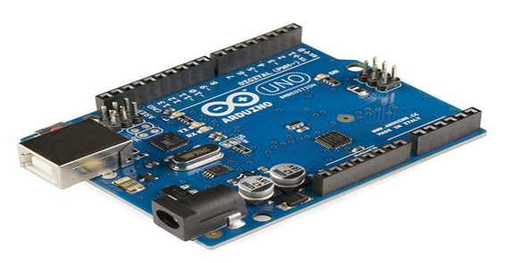

Figure 5: Arduino Uno

Figure 6: Flex Sensor

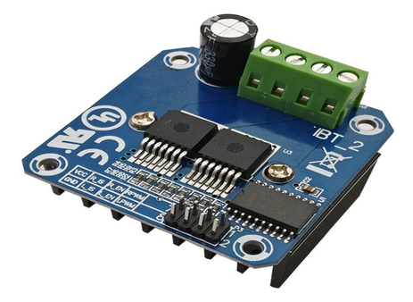

Figure 7: Motor Driver

Methods:

- The thumb mechanism was drawn in Solidworks
- Printed with 60% infil ABS plastic
- Finger pads to be dipped into flex seal to aid grip
- Supported by stainless steel pins
- Moves with a 50mm stroke motor
  - Powered by a motor driver/arduino circuit.

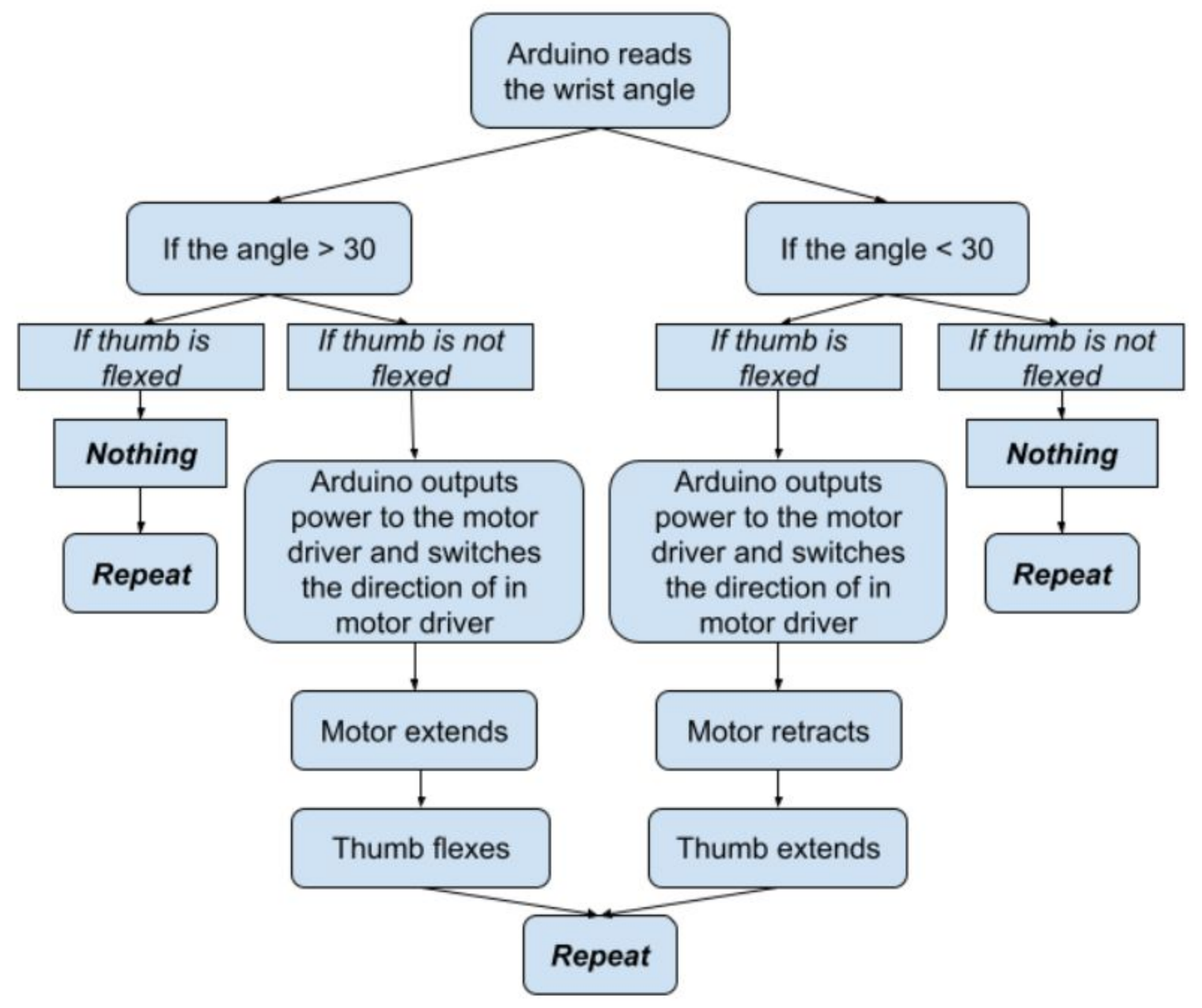

Figure 8: Flowchart of the code implementation

Testing and Results

- Basic test of motion performed (n = 10).
  - A pass/fail test to determine if replicated movement is possible.
  - Pass - consistent movement when deployed at full range
  - Fail = inconsistent movement (form of timing, force, length)
- Force output test
  - Average Max Output: 4.45N
  - Range: 3.43N to 4.91N
- Range of motion test:
  - Grasp range is 7-13 cm
  - Prosthetic moves 6 cm
  - 20 degrees of flexion measured in ImageJ
- Reaction time test:
  - Time from flex sensor deployment to full flexion of thumb
  - Compared data to the desired reaction time of 2.75 seconds
  - Significance test:
    - One Tailed Z-test
    - Reaction time >= 2.75s
    - p =0.00181
- Current project cost < $200: an affordable option for low-income individuals

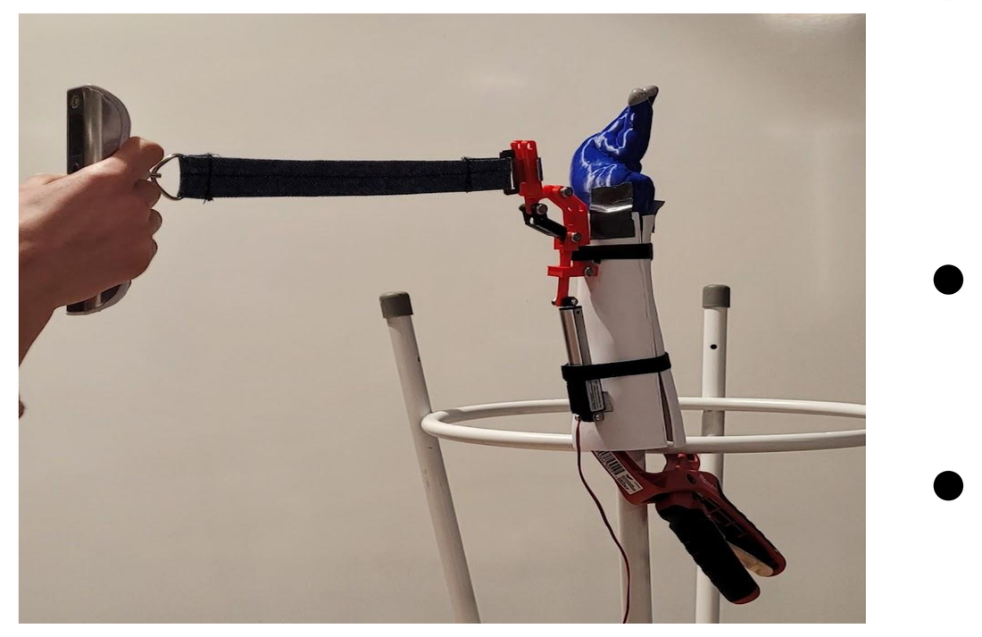

Figure 9: Picture of prosthetic successfully performing a force test

Figure 10: Picture of prosthetic successfully picking up small container.

Fabrication

Mechanism:

- The thumb mechanism moves by an upward linear motion supplying 13 cm range of motion with 20 degrees of flexion

3D Printing:

- Thumb parts designed on Solidworks and 3D printed using ABS Plastic

Cuff:

- Thermoformed to mold of patient's arm using ⅛" polystyrene

Attachment:

- Printed pieces attached using clevis pins
- Mechanical thumb attached to cuff using velcro
- Flex Seal as grip material on thumb tip for grasping

Circuit:

- Flex sensor that measures wrist flexion
- Inputs signal to Arduino Uno microcontroller
- Extension of a linear motor dependant on flexion

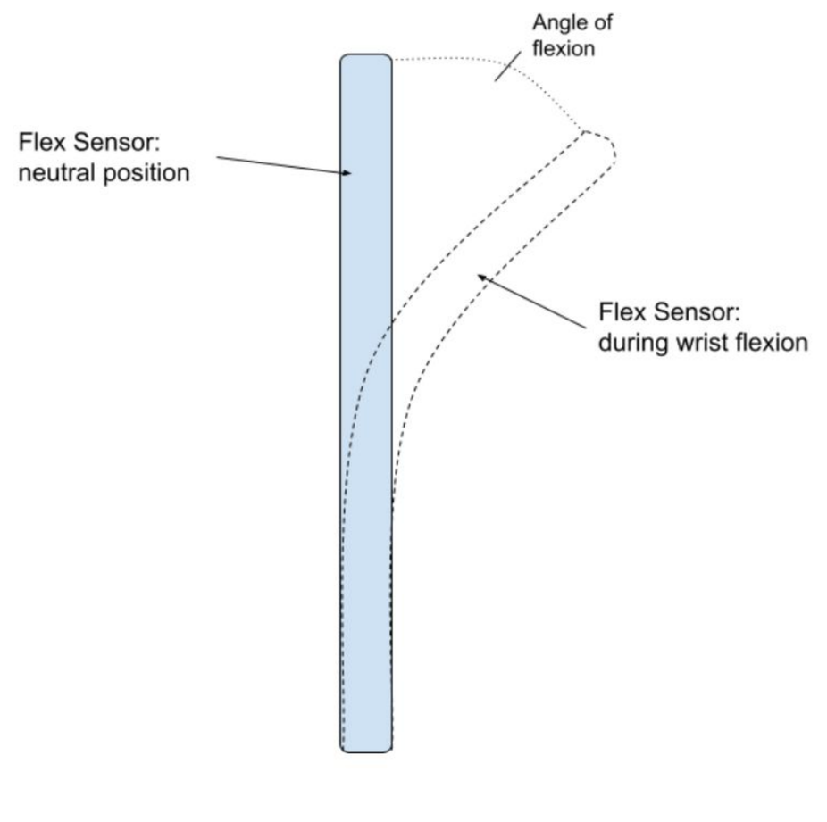

Figure 11: Model of flex sensor during wrist flexion

Final Design

- Final prosthetic manufactured based on the design criteria
- Cuff custom-made to the size of the patient's arm- to be attached tightly by velcro straps
- Motor and mechanical thumb are mounted onto the cuff
- Flex sensor is sewn into the fabric, worn underneath the cuff
  - controls the flexion of the prosthetic thumb
- More improvements to be made, but proof of concept has been achieved
- Prototype successfully demonstrated accurate range of movement
- Images of movement analyzed in ImageJ
- Accuracy of motion for Rest and full Flexion plotted in excel

Figure 12: Image of the Hand Design

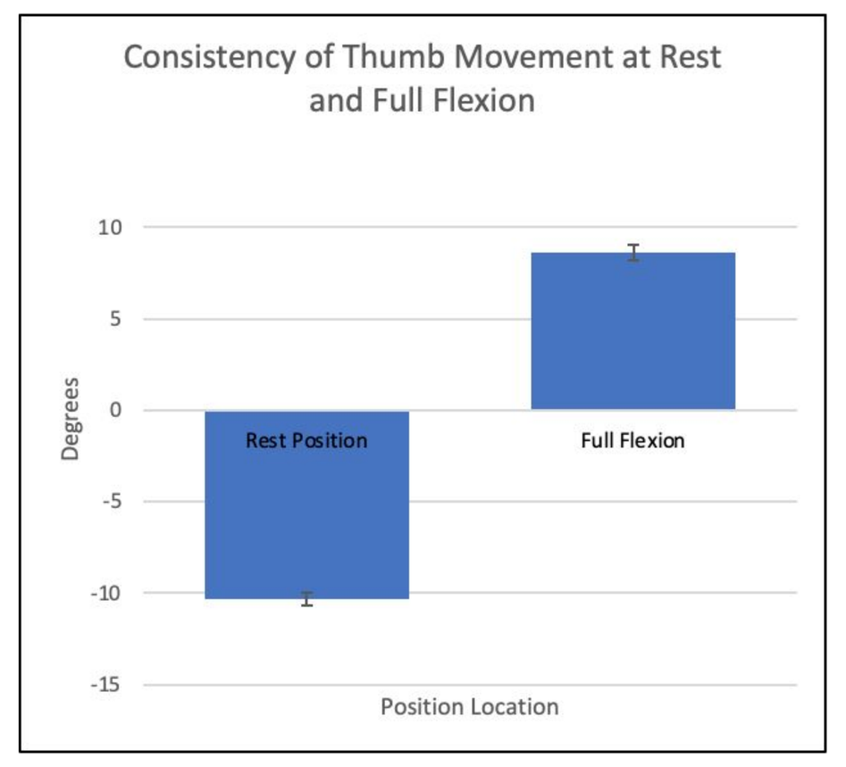

Figure 13: ROM Accuracy Analysis

Future Work

- Circuit to be condensed, soldered, and run by arduino nano
- Testing and calibration with patient to determine maximum flexion that correlates to maximum power-stroke by the motor
- Waterproof the circuitry
- Perform kinematic analysis
- Improve the mechanical design for greater movement and the addition of a writing attachment
- Make the design look more natural

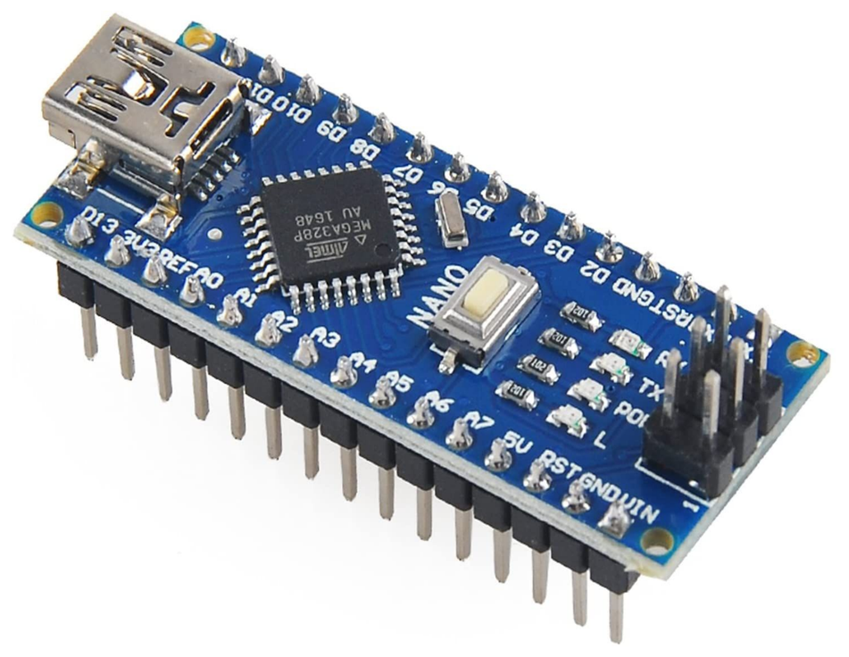

Figure 14: Arduino Nano

Acknowledgements & References

The team would like to extend thanks to our advisor Mitchell Tyler, our client Dr. Shirley Katz., Dr. John Puccinelli, and the BME Department.

[1] "Amputation: Prosthetic hand and fingers," *The Hand Society*. [Online]. Available: https://www.assh.org/handcare/condition/amputation-prosthetic-hand-and-fingers. [Accessed: 05-Oct-2021].
[2] A. Kargov, C. Pylatiuk, J. Martin, S. Schulz, and L. Döderlein, "A comparison of the grip force distribution in natural hands and in prosthetic hands," *Disability and Rehabilitation*, vol. 26, no. 12, pp. 705–711, 2004.
[3]"Bebionic hand," ottobock. [Online]. Available: https://www.ottobockus.com/prosthetics/upper-limb-prosthetics/solution-overview/bebionic-hand/#video-2. [Accessed: 19-Oct-2021].
[4] J. T. Belter and A. M. Dollar, "Performance characteristics of anthropomorphic prosthetic hands," *2011 IEEE International Conference on Rehabilitation Robotics*, 2011.
[5] L. Roberts, G. Singhal and R. Kaliki, "Slip detection and grip adjustment using optical tracking in prosthetic hands," *2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 2011, pp. 2929-2932, doi: 10.1109/IEMBS.2011.6090806.
[6] "Enabling the future," *Enabling The Future*. [Online]. Available: https://enablingthefuture.org/. [Accessed: 14-Oct-2021].
[7] "Amputations," *Sepsis Alliance*, 09-Aug-2020. [Online]. Available: https://www.sepsis.org/sepsisand/amputations/#:~:text=There%20are%2C%20on%20average%2C%20about,multiple%20fingers%2Ftoes%20and%20limbs. [Accessed: 14-Oct-2021].
[8] Huang, Bo & Li, Mingyu & Mei, Tao & McCoul, David & Qin, Shihao & Zhao, Zhanfeng & Zhao, Jianwen. (2017). Wearable Stretch Sensors for Motion Measurement of the Wrist Joint Based on Dielectric Elastomers. Sensors. 17. 2708. 10.3390/s17122708.
[9] M. P. Fahrenkopf, N. S. Adams, J. P. Kelpin, and V. H. Do, "Hand amputations," *Eplasty*, 28-Sep-2018. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6173827/. [Accessed: 20-Oct-2021].
[10] K. Ziegler-Graham, E. J. MacKenzie, P. L. Ephraim, T. G. Travison, and R. Brookmeyer, "Estimating the prevalence of limb loss in the United States: 2005 to 2050," *Archives of Physical Medicine and Rehabilitation*, 21-Feb-2008. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0003999307017480?casa_token=WUV7525Q9GYAAAAA%3AWDIh-WMRZusX7JqeFsDYZwR_5GbGcc1IKIMLPNYGhVEJNduPtDM8ZLQniDWT2t5zH3XHR_X2jMY. [Accessed: 20-Oct-2021].
[11] U. S. C. Bureau, "Health insurance coverage in the United States: 2020," *Census.gov*, 18-Oct-2021. [Online]. Available: https://www.census.gov/library/publications/2021/demo/p60-274.html. [Accessed: 20-Oct-2021].
[12] "FastStats - health insurance coverage," *Centers for Disease Control and Prevention*, 03-Aug-2021. [Online]. Available: https://www.cdc.gov/nchs/fastats/health-insurance.htm. [Accessed: 20-Oct-2021].