Designing a Lightweight and Dexterous Prosthetic Hand for EMG Control

MINES Robotics

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Introduction

Introduction to Prosthetic Hands

- For many amputees, prosthetic hands are expensive, heavy, and can only perform basic hand movements.
- The average prosthetic hand costs ~ $5000.
- The average prosthetic hand weighs 600g.

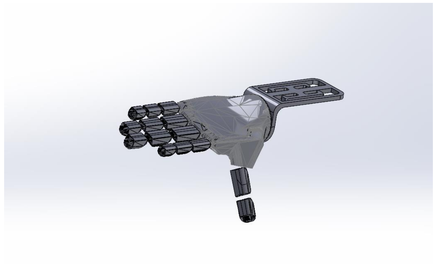


Figure 1: A 3D model of the V1 prosthetic hand design, showcasing the initial structure and layout of components.

Project Objectives

- Developing an advanced, lightweight, cost-effective, and dexterous prosthetic hand to improve functionality and user experience for amputees.
- Address the limitations of existing prosthetic devices.
- Test the repeatability and consistency of the hand positions.
- Build a data set of the 5 hand positions and how they move with respect to time for the EMG model.

Methodology

Design Methodology

- Utilizing SolidWorks and referencing both hand measurements and existing prosthetic designs, I modified and developed a custom prosthetic hand model.
- For fabrication, I chose carbon fiber PLA to ensure the hand remained lightweight while maintaining strength and durability.
- In selecting the electronics, we opted for the ESP32 microcontroller due to its exceptional computing capabilities and selected high-torque servos to enable the hand to grasp heavier objects.

Data Collection Methodology

- The code operates in two modes: Potentiometer Mode and Data Mode.
- In Potentiometer Mode, I manually adjust the hand's position and record motor encoder values.
- Data Mode moves the hand to a selected position and records motor encoder data every 50 milliseconds for 3 seconds, exporting the data in CSV format.

Testing & Evaluation Methodology

- I analyzed the data in Excel to assess the repeatability and consistency of each grasp type.
- I collected position data for each grasp type across five trials and graphed the differences to demonstrate the hand's repeatability and consistency.

Grasp Type Methodology

- I selected five common grasp types, based on Ninapro data, that represent the most frequently used hand positions in daily activities and can be easily replicated by prosthetic hands.

Grasp Type Data

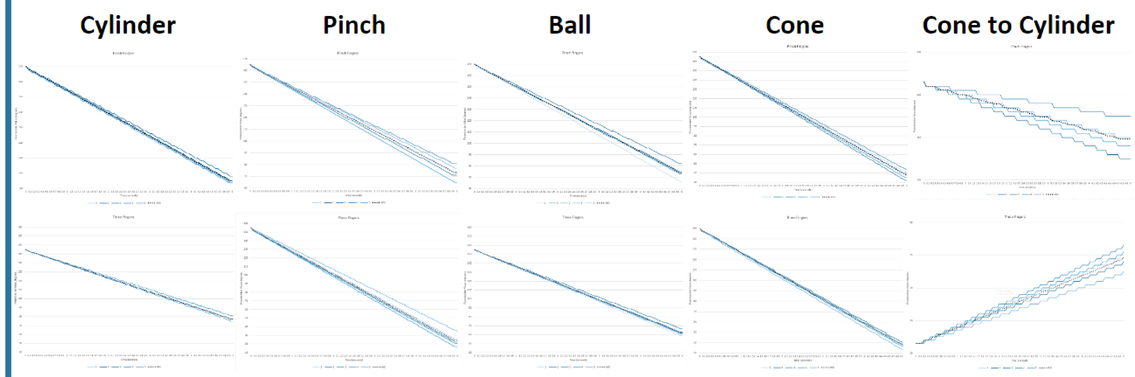


Figure 5: Illustrates the precision of the selected grasp types, showing how the prosthetic hand maintains each grasp over a 3-second interval. The data points represent the hand's position accuracy at time intervals, showing any deviations in motor control.

Component	Qty	Price	Total Price
High Torque Servo	2	$19.95	$39.90
3.3v Servo	1	$5.95	$5.95
ESP32 v2	1	$19.95	$19.95
Breadboard	1	$2.90	$2.90
Potentiometer	3	$2.95	$8.85
Wires	25	$0.03	$0.75
Nylon Paracoord (ft)	5	$0.14	$0.70
Shock Coord (ft)	4	$0.18	$0.72
3d Print (grams)	90	$0.04	$3.15
Power Supply	1	$5.49	$5.49
		Total	**$88.36**

Figure 6: Shows the cost breakdown of the final prosthetic hand design.

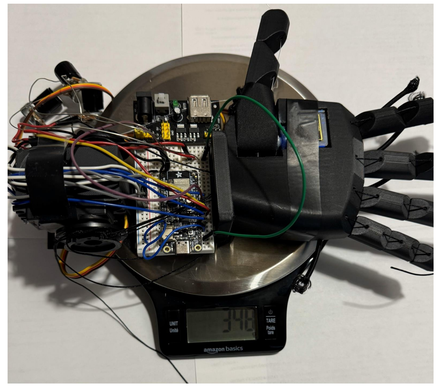


Figure 7: Shows the weight in grams of the final hand design.

V1 & V2 Design

V1 Goals

- Design a basic prosthetic hand to evaluate different grasp movements and types.
- Test and optimize finger sizing and positioning for improved functionality.
- Determine the appropriate electronics required for the hand and reduce the size of the components.
- Develop and test code to control hand movements and collect relevant performance data.

V2 Goals

- Mount servos on the wrist brace for enhanced stability and optimal positioning.
- Further reduce and organize the electronics for a more compact and efficient design.
- Improve ball and cylindrical grasp capabilities by adding a servo to independently control thumb movement.

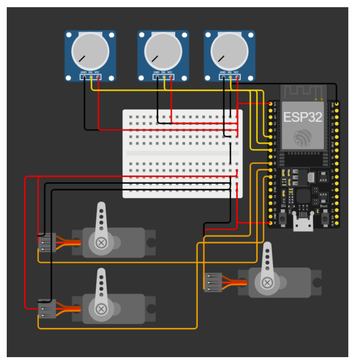
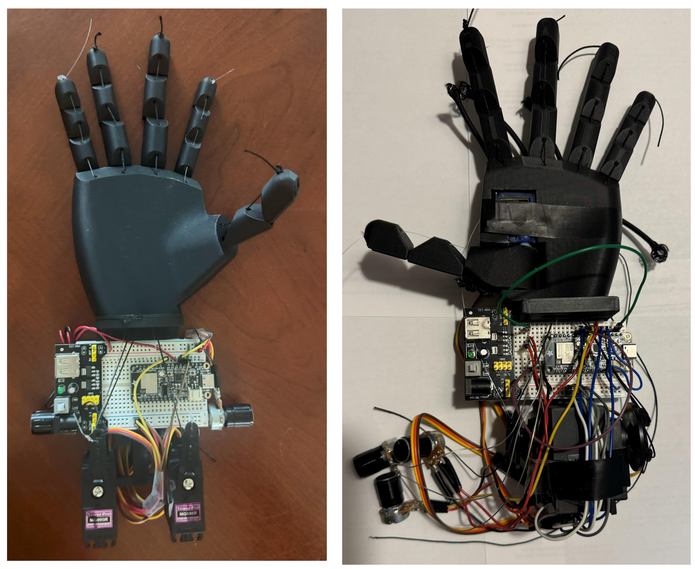


Figure 2: An electronics diagram showcasing the wiring that controls the prosthetic hand.

V1 Design

V2 Design



Figures 3 & 4: Finalized and original prosthetic hand designs, with V1 shown on the left and V2 on the right, highlighting the progression in design and functionality.

Conclusion and Future Directions

Key Findings

- The prosthetic hand weighs 348 grams, 42.27% lighter than the models on the market. The material cost is $88.36, 56.59 times cheaper than the average model.
- The data collected was significant in ensuring the prosthetic hand's consistency and repeatability through extensive testing and refinement. Each
- The hand, as the first two-servo prosthetic that can rotate objects without using a wrist joint, represents a significant leap forward in the field of prosthetics.

Future Directions

- Gather data and do more extensive testing with the new prosthetic hand design.
- Print custom circuit boards to further size down and simplify the electronics.
- Test the hand with the EMG model and combine the hand data with the EMG data.

References and Acknowledgements

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