2025-2026 Smart Prosthetics PDR

ME 486A Peter Bishay

9th Cohort Team Members:
Abdulrahman Al Dulaimi, Jorge Alvarez, Justin Brown, Cesar Flores Velasquez, Nathan Handal, Chris Lopez, Vanessa Montejano, Hao Phan, Matthew Portillo, Sergio Rivas, Kainen Shaw, Yaroslav Tretiak, Kurt Trocino, Katsuki Yasuda

Agenda

- Problem Statement
- Arm Design
  - History
  - Adaptive Attachment system
  - Current arm design
- Foot Controller System
  - History
  - Current design
  - Neural networks
- Haptic Feedback
  - History
  - M.I.D.A.S. Haptic system
- Q&A

Problem Statement

- Most prosthetics are made for amputees and can't be used by people with temporary arm or shoulder injuries.

- They are often expensive and not ideal for short-term use or rehab.

- They often rely on EMG-controle which can be unreliable due to skin or muscle issues.

- Few provide real sensory feedback, and those that do give limited response.
  - Vibrotactile (vibrations)
  - Electrotactile (electricity)

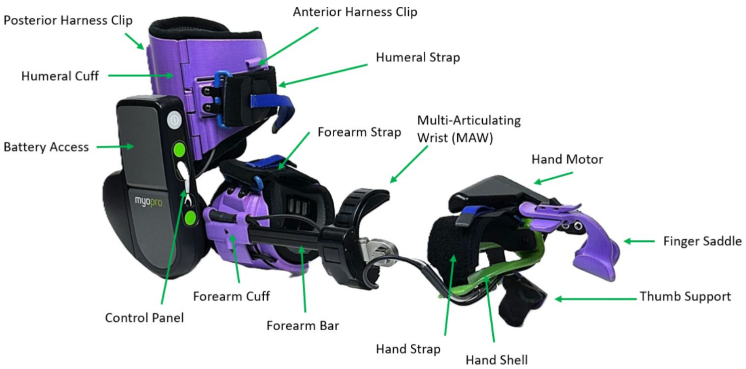
Arm Design

Team members:
Abdulrahman Al Dulaimi, Justin Brown,
Cesar Flores Velasquez, Sergio Rivas,
Yaroslav Tretiak, Katsuki Yasuda

Goals & Objectives

- Create a lightweight user friendly modular robotic arm.
  - Wearable Third Arm
  - Shoulder-and-Below Prosthetic
- Fast attach/swap: one-handed, tool-free connections
- Safe & reliable
- Range of motion:
  - 1 DOF in the shoulder and elbow
  - 2 DOF in the wrist
- Weight of complete system ~2.2 kg (5 lb)
- Finger Grip Strength ~60 N

What is currently on the market?



Kinova Assistive: Jaco Arm

- Third arm system targeted for wheelchair users
- Controlled with joystick

MyoPro

- "designed to help restore function to the wearer's paralyzed or weakened upper extremities"

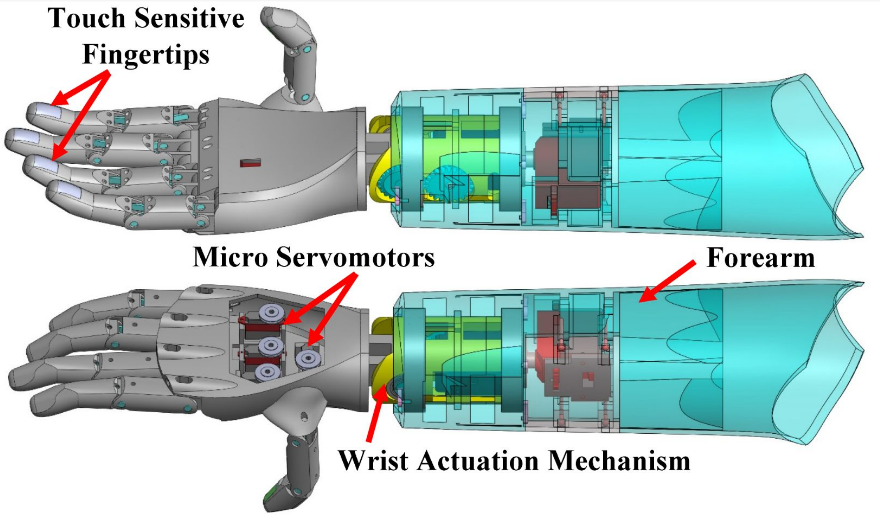
Other Third Arm Systems

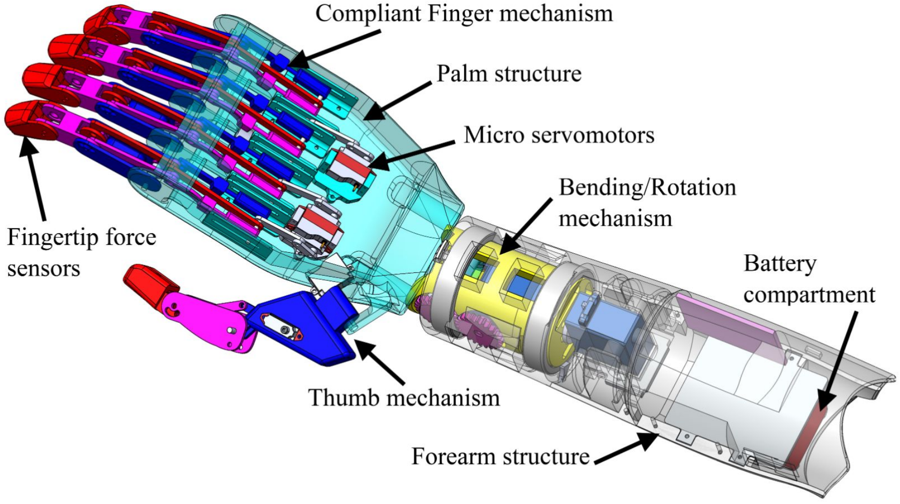
Jizai Arms

- Focused for Aesthetics
- Attach & Detach in multiple mounting points
- Controlled by external user

Nahoko Yamamura, Daisuke Uriu, Mitsuru Muramatsu, Yusuke Kamiyama, Zendai Kashino, Shin Sakamoto, Naoki Tanaka, Toma Tanigawa, Akiyoshi Onishi, Shigeo Yoshida, Shunji Yamanaka, and Masahiko Inami. 2023. Social Digital Cyborgs: The Collaborative Design Process of JIZAI ARMS. In Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23). Association for Computing Machinery, New York, NY, USA, Article 369, 1–19. https://doi.org/10.1145/3544548.3581169

5th and 6th Cohort Arms





5th Cohort

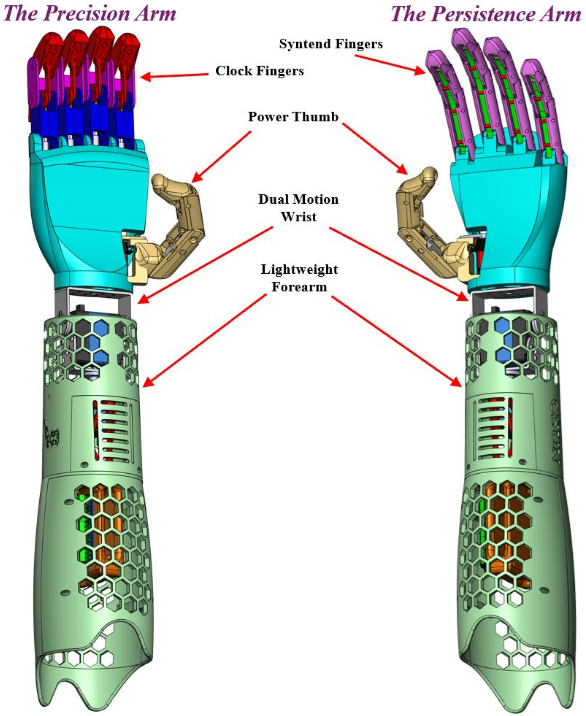
- 1 DOF Fingers & Thumb
- Tendon Base

6th Cohort

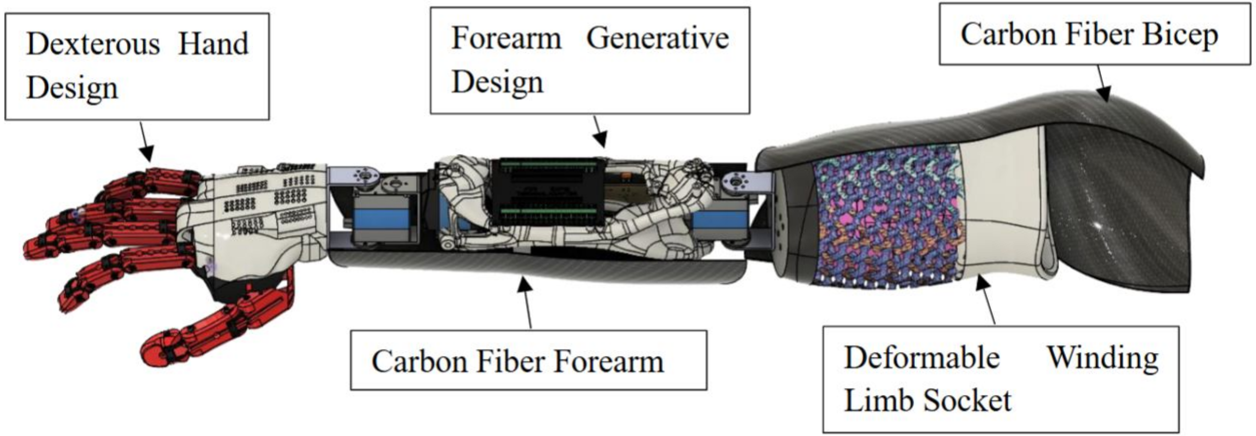
- 1 DOF Fingers, 2 DOF Thumb
- Link Based

7th Cohort "Precision" & "Persistence" Arm

- Elbow-and-Below Prosthetic
- Precision Arm: Link based joints
- Persistence Arm: Tendon based joints
- 1 DOF Fingers
- 2 DOF Thumb
- Fusion's Generative Design

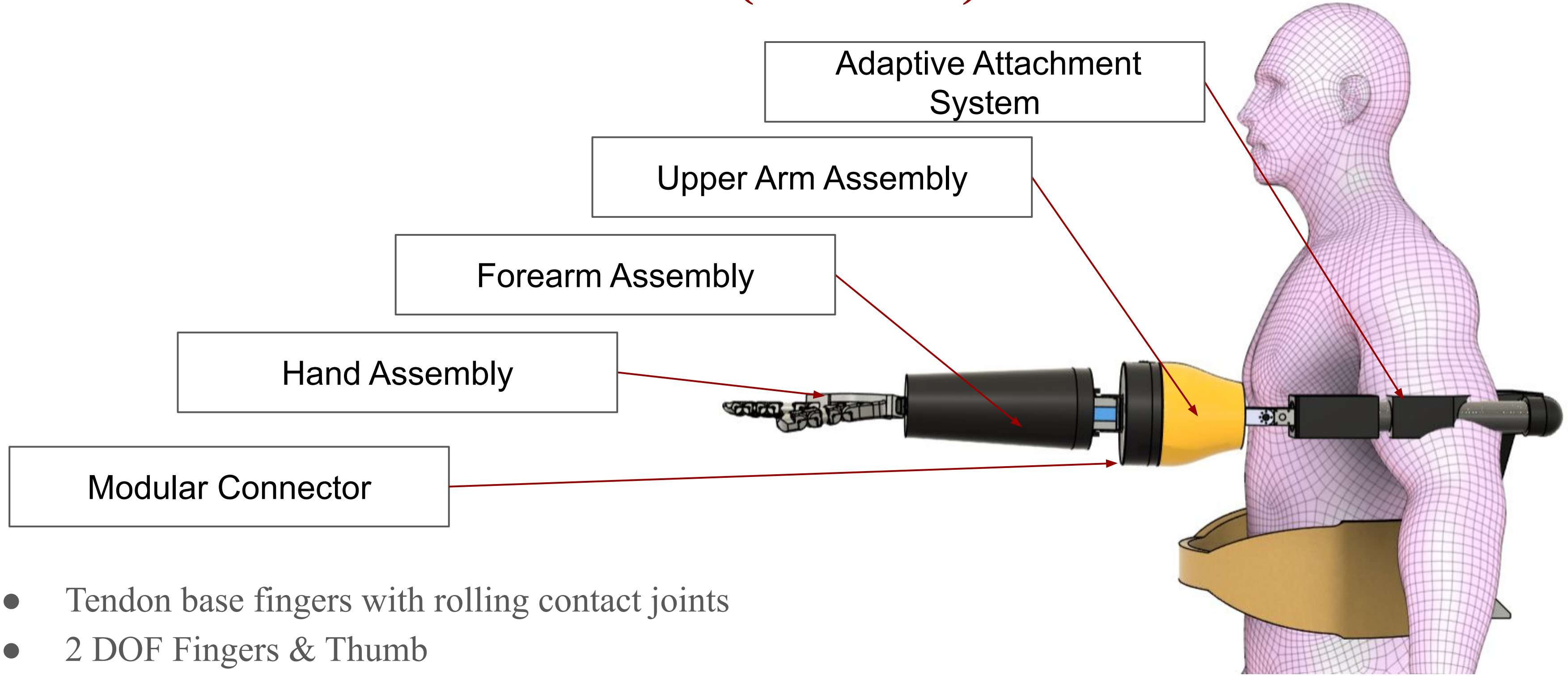


8th Cohort "Prometheus" Arm



- Shoulder-and-Below Prosthetic
- Tendon based fingers with Rolling Contact Joints
- 2 DOF Fingers & Thumb
- Generative Design

9th Cohort “Cerberus” Arm (Current)



- Tendon base fingers with rolling contact joints
- 2 DOF Fingers & Thumb
- Attachment system for comfortable, stable, and modular wearability.

The Adaptive Attachment System allows the wearable robotic arm to be used in various ways such as

Figure showing the Kinova Assistive: Jaco Arm

Figure showing robot arm on the Robot fixture table from Cabot Depot

Figure showing a hydraulic wearable arm from Université de Sherbrooke in Canada

https://assistive.kinovarobotics.com/product/jaco-robotic-arm
https://spectrum.ieee.org/robotic-third-arm-can-smash-through-walls

What is the Adaptive Attachment System

- Allows robotic arm to quickly connect to different mounts or tools.
- The locking mechanism keeps the arm stable and prevents accidental release

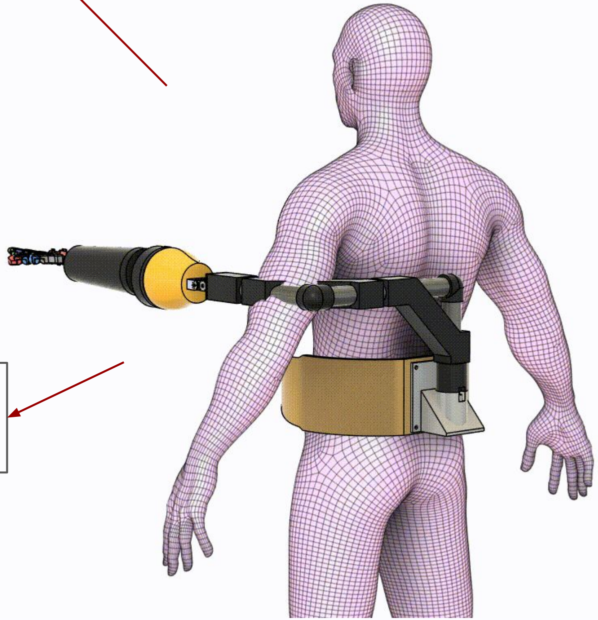
- Designed so users can attach or detach easily, even with limited dexterity.
- Users can switch attachments or mounting points in seconds, without tools

Adaptive Attachment System

Version 1 of the Adaptive Attachment System

Functions as the natural extension of the user

On-the-hip belt quick attachment system



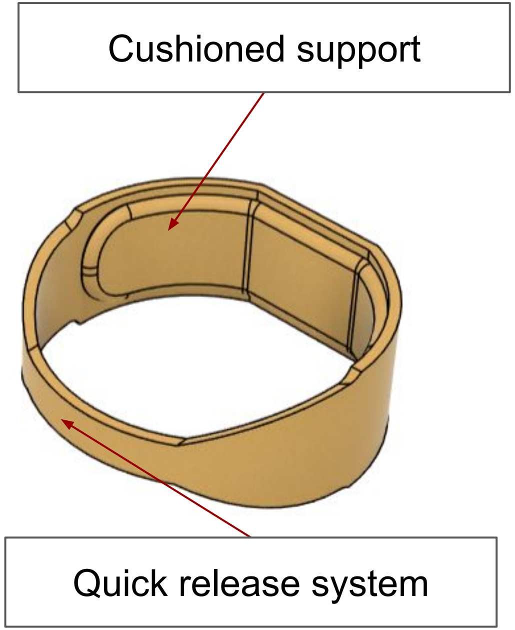
Carbon fiber shoulder quick attach system

On the hip wearable design

Quickly connect and disconnect robot arm from system

On-the-hip Belt Connector

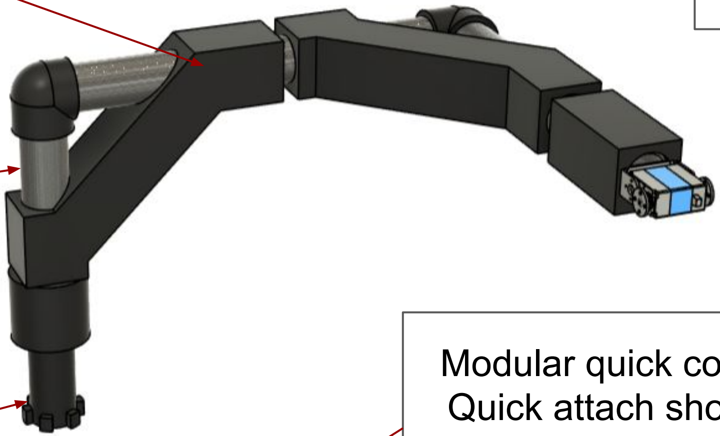
- Belt mounted version of the Adaptix attachment system
- Main support is worn around the waist reducing strain on the upper body of the user.
- Must be easy to attached and detach from user with one arm and minimal dexterity
- Acts as the foundation for the shoulder assembly that connects the arm to the Adaptix system



The shoulder

FDM Angle support Frame: Generative design

Shoulder motor + controller



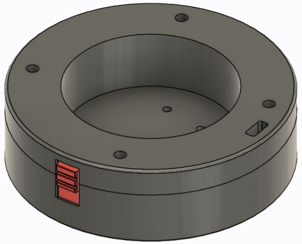
Carbon Fiber Tube: lightweight and rigid

Modular quick connector: Quick attach shoulder to the on-the-hip belt connector

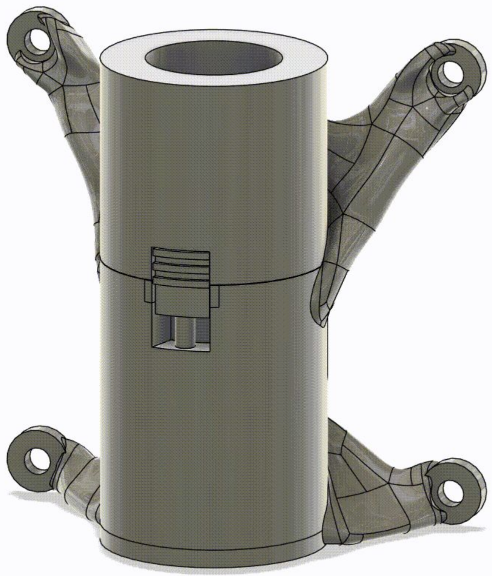
Modular Connector. Connects to the on-the-hip belt

Modular Connector

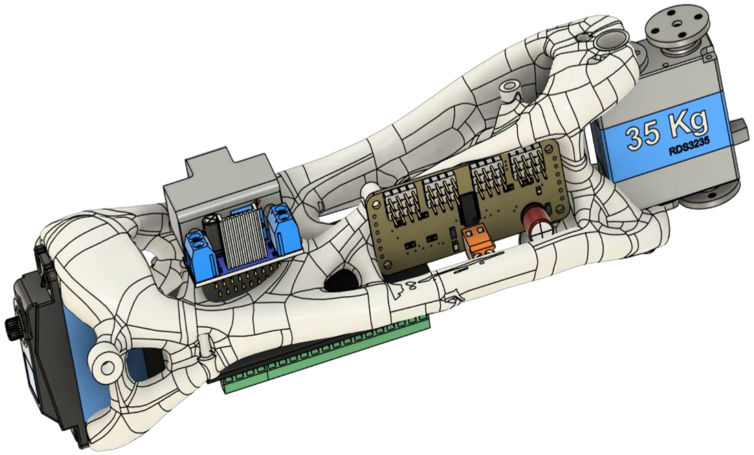
- Enables easy attachment and detachment of the prosthetic arm in multiple locations.
- Smart Connector: made for the bicep, has mag link wires to allow wires to attach and detach.




Smart Connector



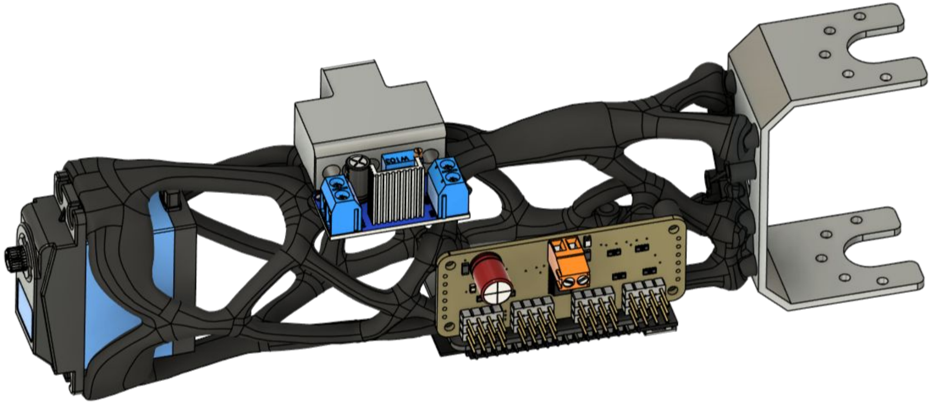
Forearm



8th cohort Generative design forearm

Net Weight: 134 grams

Material : ABS



Current Generative design forearm

Net Weight: 57 grams

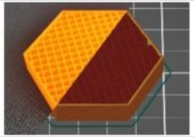
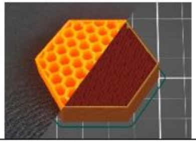
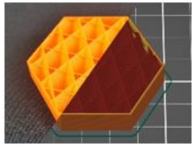
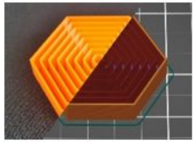
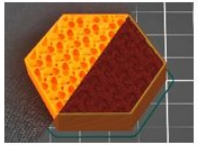
Material : 20 % Carbon Fiber Reinforced Nylon 6

Forearm Material Selection

Property	ABS	PC (Polycarbonate)	Fiberon PA6-CF20
Strength & Stiffness	Moderate (~40 MPa, 2 GPa)	High (~60 MPa, 2.4 GPa)	Very high (~110 MPa, 8.6 GPa)
Weight / Density	Light (1.05 g/cm³)	Moderate (1.20 g/cm³)	Light-moderate (1.17 g/cm³)
Heat Resistance (HDT)	~100 °C	~115 °C	~215 °C
Durability	Good impact, moderate rigidity	Excellent impact, moderate rigidity	Very stiff, lower impact flexibility
Printability	Easy; moderate warp	Difficult; needs enclosure	Moderate; needs dry filament & hardened nozzle
Best Use Case	Basic prototypes	Tough shells needing impact strength	High-stiffness lightweight structural parts

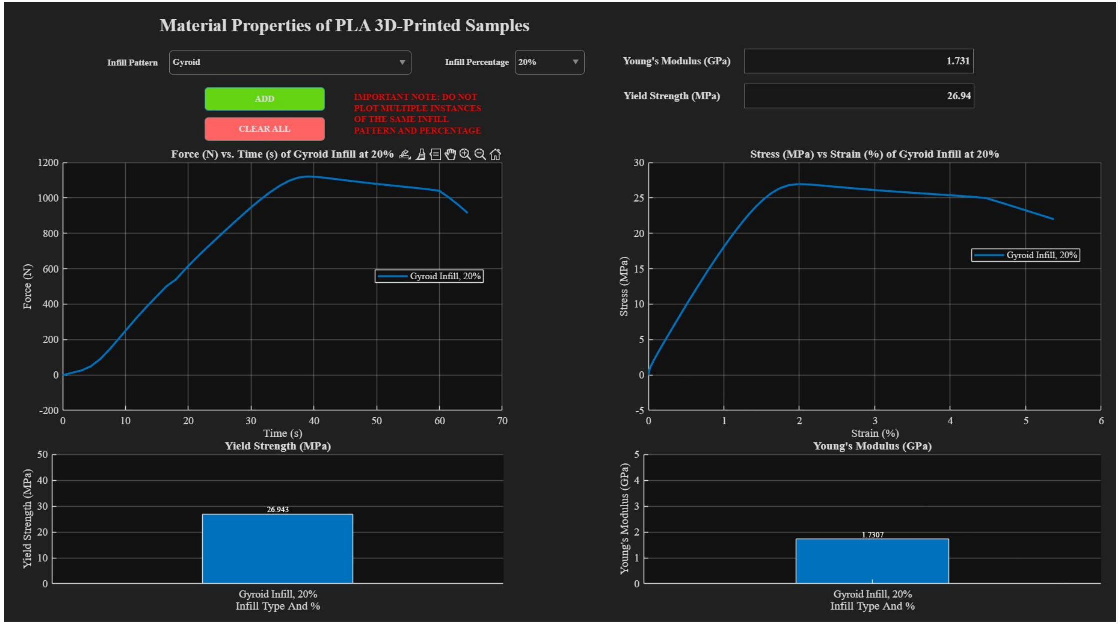
20% Carbon Fiber Reinforced Nylon 6 (PA6-CF20) will be used due to its high stiffness-to-weight ratio along with its professional-grade mechanical performance great for load bearing components.

Forearm Material Selection

Infill Type	Characteristics	Advantages	Limitations	
Rectilinear	• Straight intersecting lines	• Simple and fast	• Stress concentrates at intersections	
Honeycomb	• Hexagonal cells	• Efficient load spreading in 2D plane	• Limited Z-direction strength • Longer print time	
Cubic	• 3D lattice of cubes	• Balanced x, y, z regidity with easy slicing	• Higher material use	
Concentric	• Rings following part perimeter	• Excellent outer wall bonding	• Poor internal regidity	
Gyroid	• Continous 3D periodic surface with no sharp corners	• Isotropic mechanical strength in all directions • High stiffness-to-weight ratio	• Relative higher computation for slicing	

"Infill Patterns." *Prusa Knowledge Base*, https://help.prusa3d.com/article/infill-patterns_177130.

Forearm Material Selection

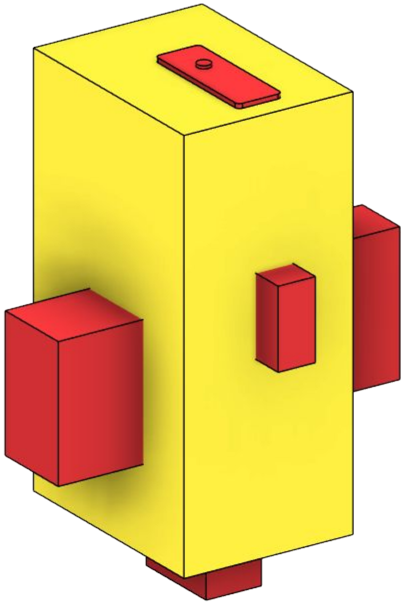


MatLab App Results

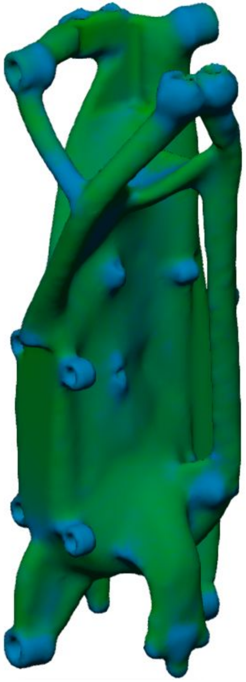
Material	Printed PLA 20% Gyroid
Density	1.14E-06 kg /mm^3
Young's Modulus	1.731 Gpa
Poisson's Ratio	0.36
Yield Strength	26.94 MPa
Ultimate Tensile Strength	28.10 MPa
Thermal Conductivity	1.600E-04 W/(mm C)
Thermal Expansion Coefficient	8.570E-05 / C
Specific Heat	1800.00 J/(Kg C)

Fusion Material Properties

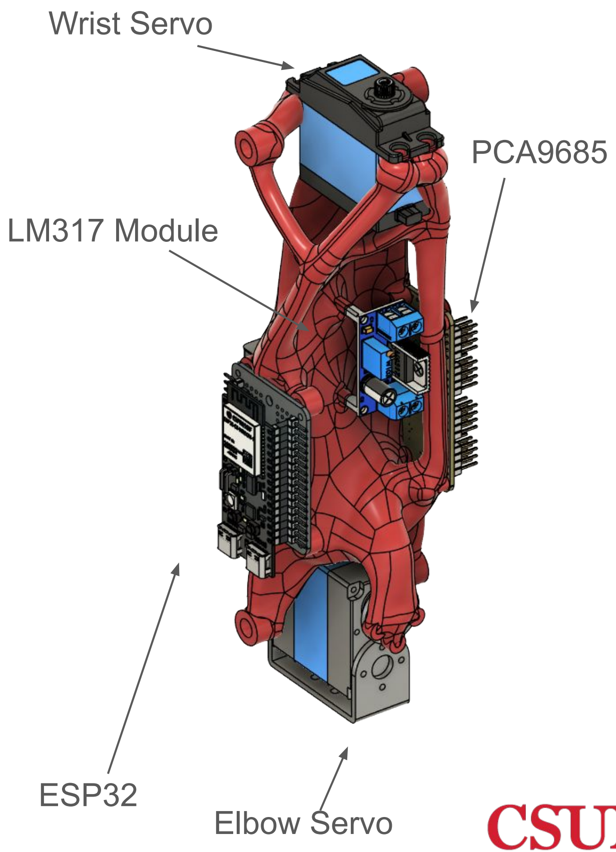
Forearm Material Selection



Obstacle and
Starting Shape

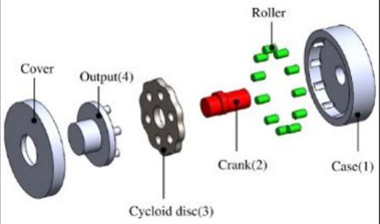


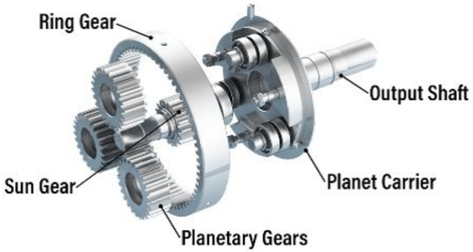
Stress View



Gear Reducer

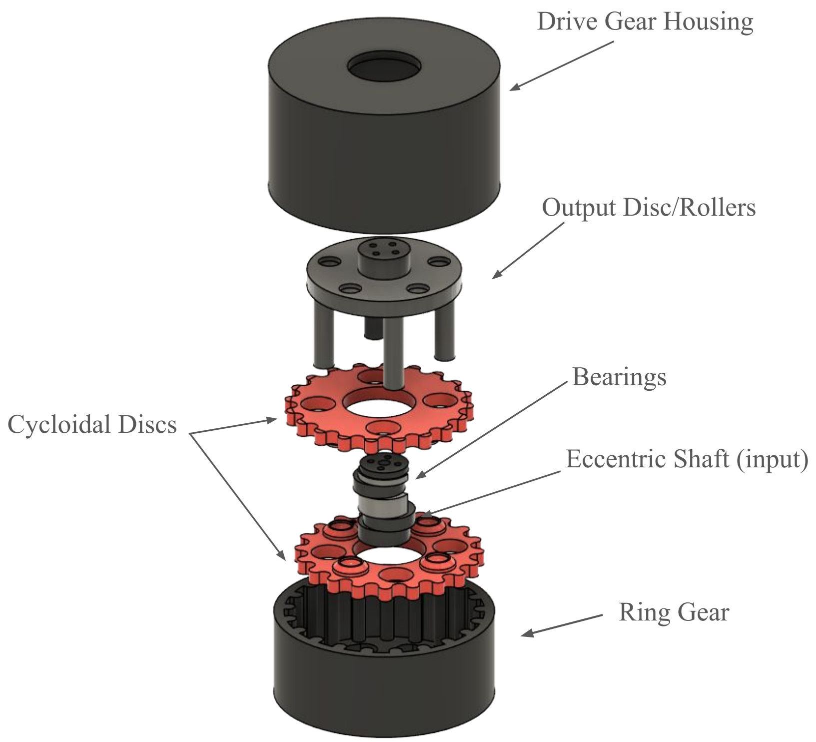
Feature	Cycloidal	Planetary	Harmonic
Reduction Ratio	High (≤203:1)	Low (≤10:1, Multi-stage for high ratio)	High (≤160:1)
Torque Density (Nm/kg)	High (≤76.3 Nm/kg)	Medium (≤44.16 Nm/kg)	Medium-High (≤59.14 Nm/kg)
Weight	Heavy-weight	Medium-weight	Light-weight
Backlash (Precision)	Low (≤1.5 arc.min)	Medium (≤5 arc.min)	Zero
Torsional Rigidity	High (≤3,334 Nm/arc.min)	Medium (≤850 Nm/arc.min)	Medium (≤903 Nm/arc.min)





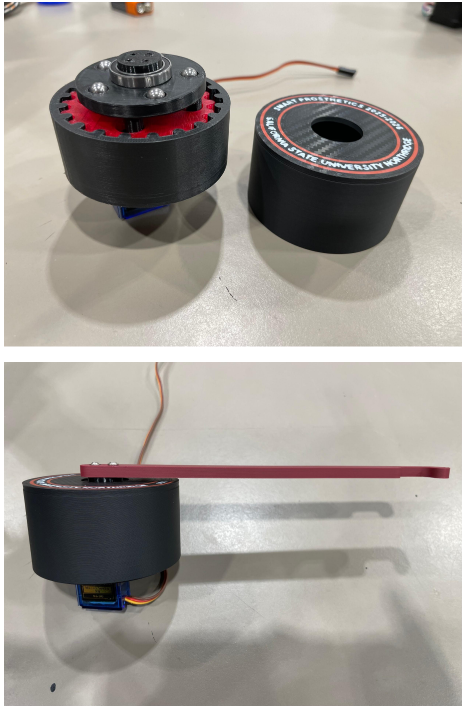
Cycloidal Gear System

- Benefit:
  - Cycloidal drives provide high gear reduction in a smaller volume.
- Cons:
  - Servos are still limited (stepper motors typically used), gear wear, and complexity of integration.
- Micro Servo (SG90) Test
  - Transmission Ratio 21:1
  - Ideal no losses 0.15 Nm torque to 3.15 Nm
  - 70% Efficiency torque output 2.6 Nm

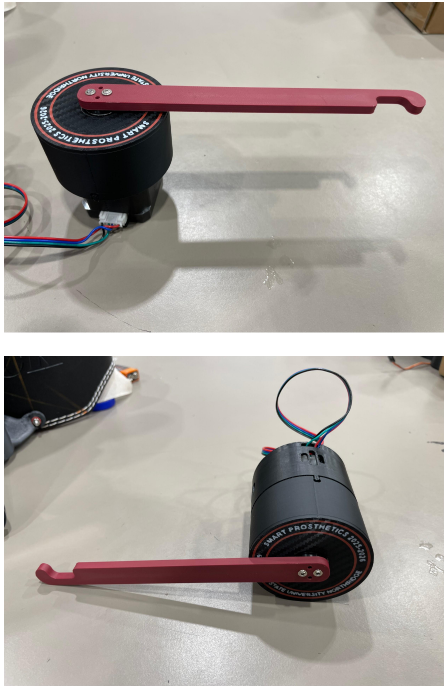


Micro Servo Test

Cycloidal Gear System



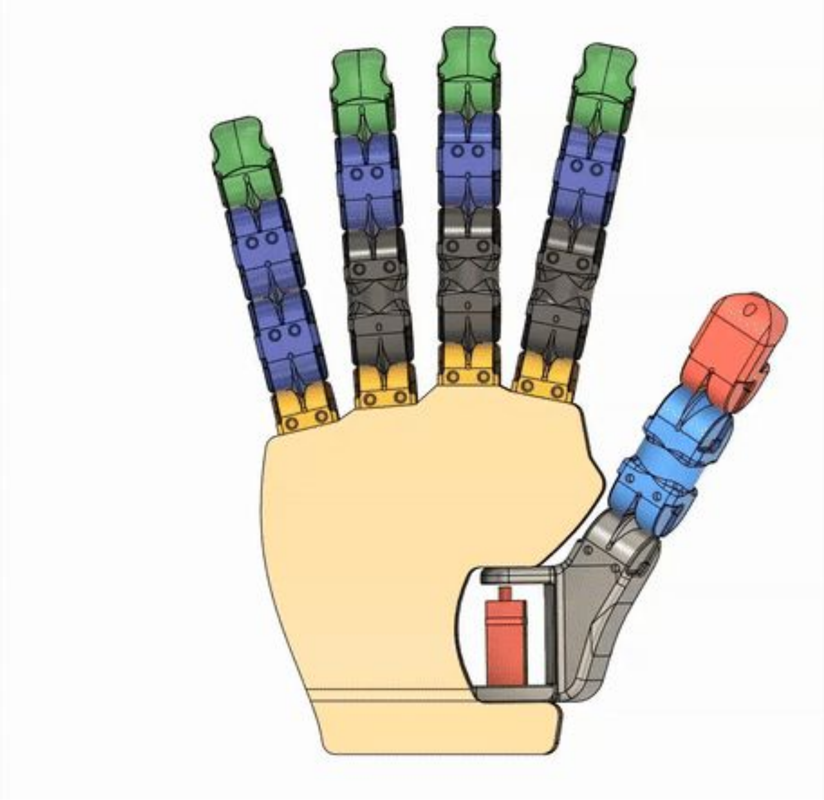
SG90 Cycloidal Gear Drive



Stepper Motor Cycloidal Gear Drive

“Cerberus” Hand Design

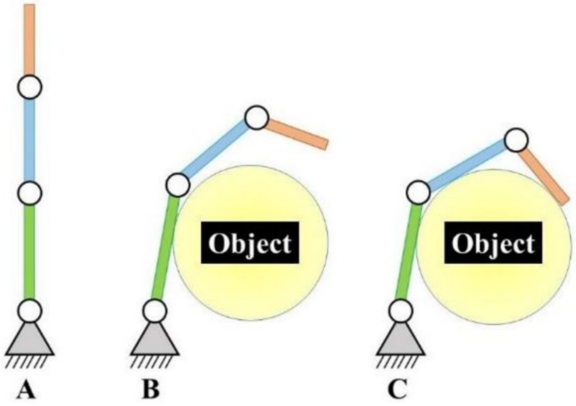
- FDM printed fingers for lighter weight
  - 45% weight reduction: 25 g → 13g
  - 8th cohort utilized SLA (Resin Printing)
- Rolling Contact Joints
- Tendon Connections
- 1 Servo / Finger
  - Lighter Weight
- 2 Servos for Thumb
  - Adduction/Abduction
  - Flexion/Extension

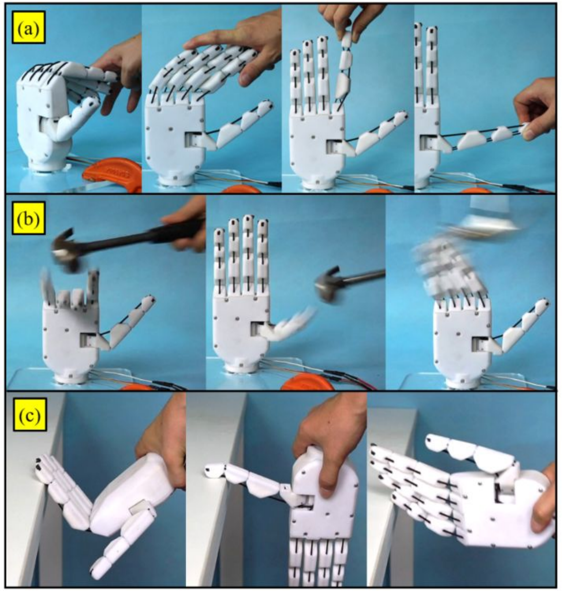


Joint Type

Rolling Contact Joints:

- Dislocates
- Compliant
- Biomimetic





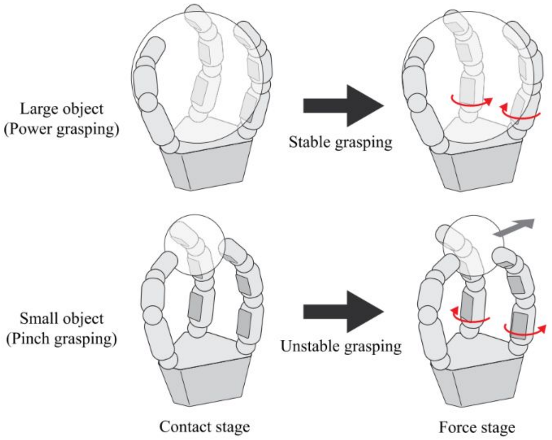
Gorjestani, Aryan & Samavati, Farzad. (2023). ATLAS Finger: a Prosthetic Finger Mechanism for Robotic applications. 9. 1-10.

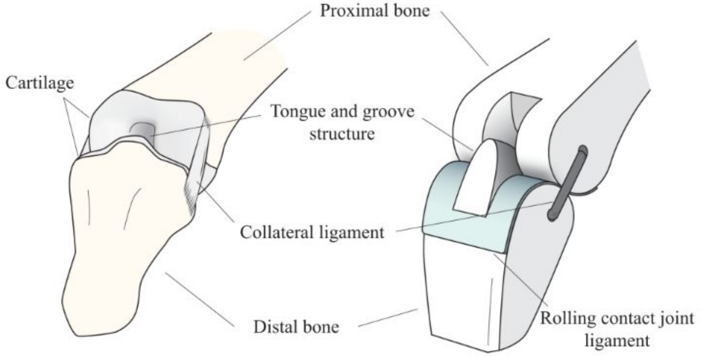
H. Liu, K. Xu, B. Siciliano and F. Ficuciello, "The MERO Hand: A Mechanically Robust Anthropomorphic Prosthetic Hand using Novel Compliant Rolling Contact Joint," 2019 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM), Hong Kong, China, 2019, pp. 126-132, doi: 10.1109/AIM.2019.8868520.

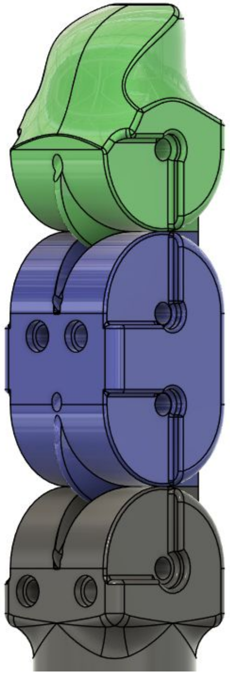
Joint Selection Cont’d

Anthropomorphic Rolling Contact Joint:

- Tongue & Groove Design
- Torsional stiffness passively increase
- Build off 8th Cohort







“Cerberus” Finger

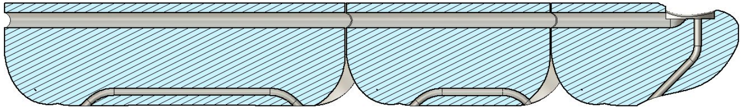
S. Kim, E. Sung and J. Park, "ARC Joint: Anthropomorphic Rolling Contact Joint With Kinematically Variable Torsional Stiffness," in IEEE Robotics and Automation Letters, vol. 8, no. 3, pp. 1810-1817, March 2023, doi: 10.1109/LRA.2023.3243439.

Connection Type

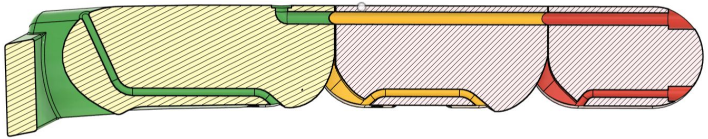
Tendon-Based System:

- Minimal Complexity
- Light Weight
- Biomimetic

- Flexion: Synthetic Nylon Wire
- Extension: Elastic Band



“Cerberus” Finger



“Cerberus” Thumb

Actuation Method

Compared various actuation mechanisms

Conclusion:

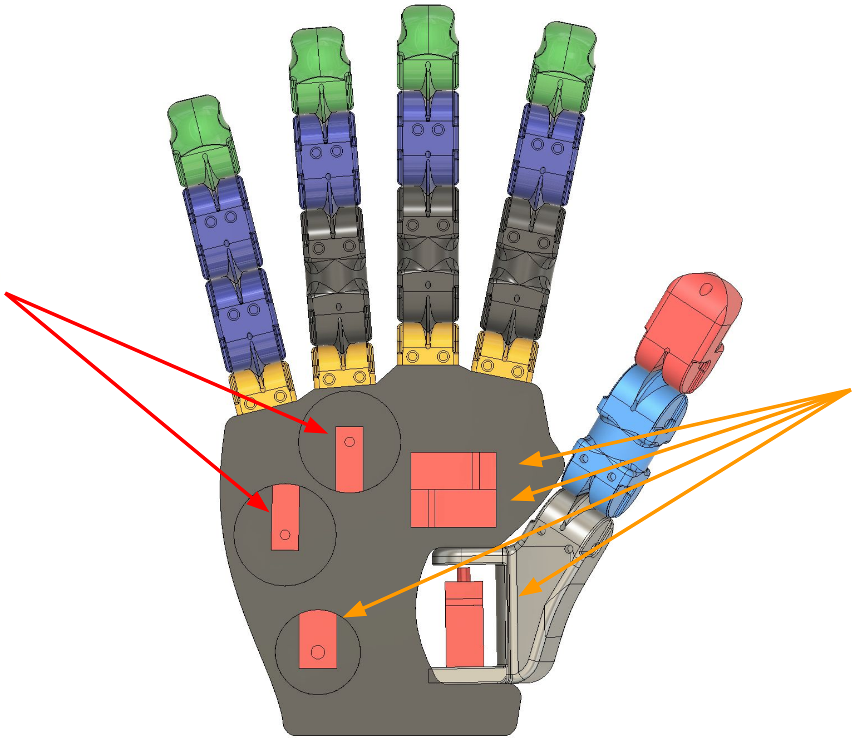
1 Motor/Finger for

- Simplicity
- Lighter weight
- Space in palm
- Gestures

ServoMotor System					
	DOF	Pros	Cons	# of Servos	Tendon Tension/Output
1 Motor/Finger	1	Space on palm Light Weight Gestures	1 DoF	4 + (2)	6.3 kgcm ~ 10.9 kgcm
2 Motor/Finger	2	Range of Motion Grip Strength Gestures	tighter space more motors = Heavier	6 + (2)	6.3 kgcm ~ 10.9 kgcm
2 Motor/Finger (Splay)	2	Range of Motion Increase Grip Area Gestures	tighter space more motors = Heavier	6 + (2)	6.3 kgcm ~ 10.9 kgcm
MERO Hand	1	2 motors for whole hand Simple mechanism	Strength Limited Gestures(Close/Open)	1 + (1)	3.6 N (avg grasp)
Differential Pulley	1	Even distribution of load with 1 motor Adapting to item	1 DoF Thumb Design Limited gestures: Close/Open Takes Space Friction in tendon and pulley	1 + (1)	24.19 +/- 1.91 N
Four Output Gear Differential	1	Even distributon of load Requires 2 motors	Complicated Design Not compact Heavy (169.8g) Limited Gestures (x4)	2 + (2)	39 N
Whiffletree mechanism	1	Even distribution of load Total of 16 finger combinations	Manually lock differential mechanism, Require additional space precision tension calibration	1 + (1)	42.8 N

Servo Motor Selection

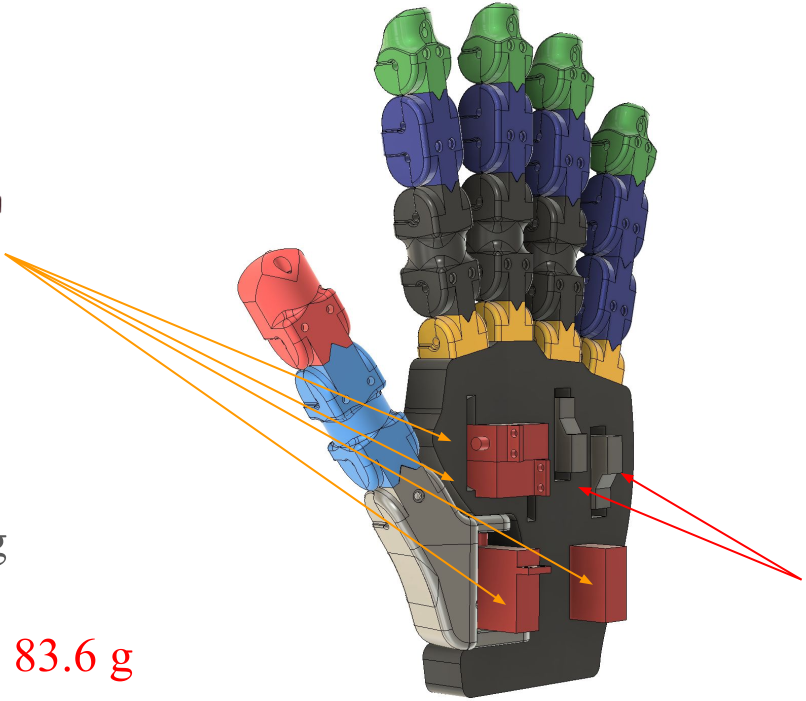
KST A08



MKS HV6150H

Servo Motor Selection

	Torque (kgf.cm)	Voltage (V)	Weight (g)	Length (mm)	Width (mm)	Height (mm)
KST A08	1.4	3.8	7	23.5	8	19
	2.2	6				
	2.8	7.4				
	3.2	8.4				
MKS HV6150H	6.3	4.8	17.4	23.5	11	25
	8.2	6				
	9.8	7.4				
	10.9	8.2				



4x MKS motors: 69.6 g
2x KST motors: 14 g
Total weight of Servos: 83.6 g

Servo Motor Selection

Name	Torque (kgf.cm)	Voltage (V)	Weight (g)	Length (mm)	Width (mm)	Height (mm)
KST A08 LV	1.2	3.5	7	23.5	8	19
	2.0	4.2				
KST HS08B HV	2.8	3.8	11	23.5	8	25.25
	4.5	6				
	5.2	7.4				
	6	8.4				
KST X08	1.4	3.9	8	23.5	8	16.8
	2.2	6				
	2.8	8.4				
KST X08 Plus	2.4	3.8	9	23.5	8	16.8
	3.85	6				
	4.85	7.4				
	5.3	8.4				
KST X10	6.2	4.8	28	30	10	35.5
	7.5	6				
	9.5	7.4				
	10.8	8.4				

Future Works

- Attachment:
  - Develop/ build the upper arm assembly
  - Develop the electronics for the Adaptive Attachment System
- Forearm:
  - Testing Nylon 6 carbon fiber
  - Build forearm assembly
- Hand:
  - Manufacture and test the grip strength of the hand
  - Collaborate with Foot Control to assign various unique gestures

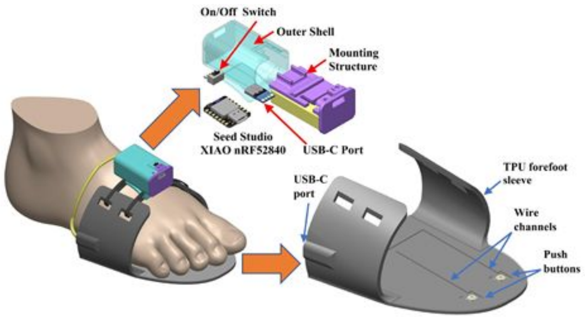
Foot Controller System

Team Members:
Kurt Trocino
Kainen Shaw
Matthew Portillo
Hao Phan

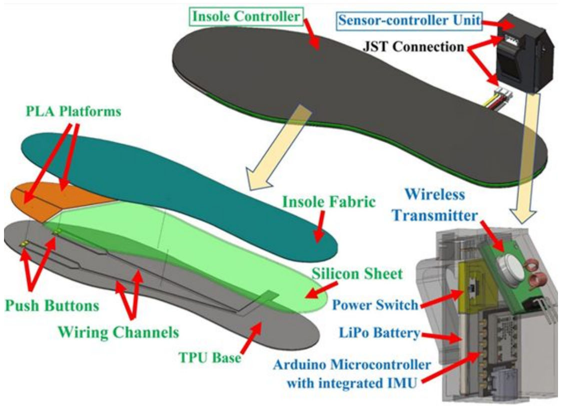
Smart Prosthetic Foot Controller History

- Noninvasive
- Low Cost
- Ease of use

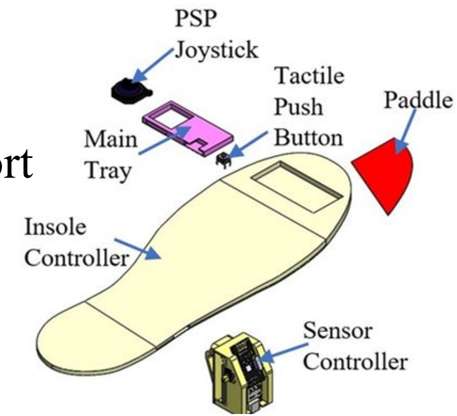
7th Cohort



5th Cohort



6th Cohort



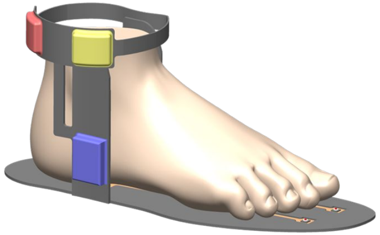
8th Cohort Foot Controller Pros and Cons

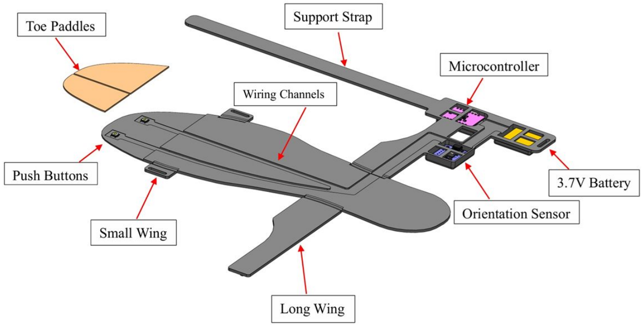
Pros:

- Thin, easy to put into shoe
- Does not affect walking
- Relatively easy to use

Cons:

- The IMU fixture is not rigid
- The strap does not securely affix to user's body
- Shoe dependent



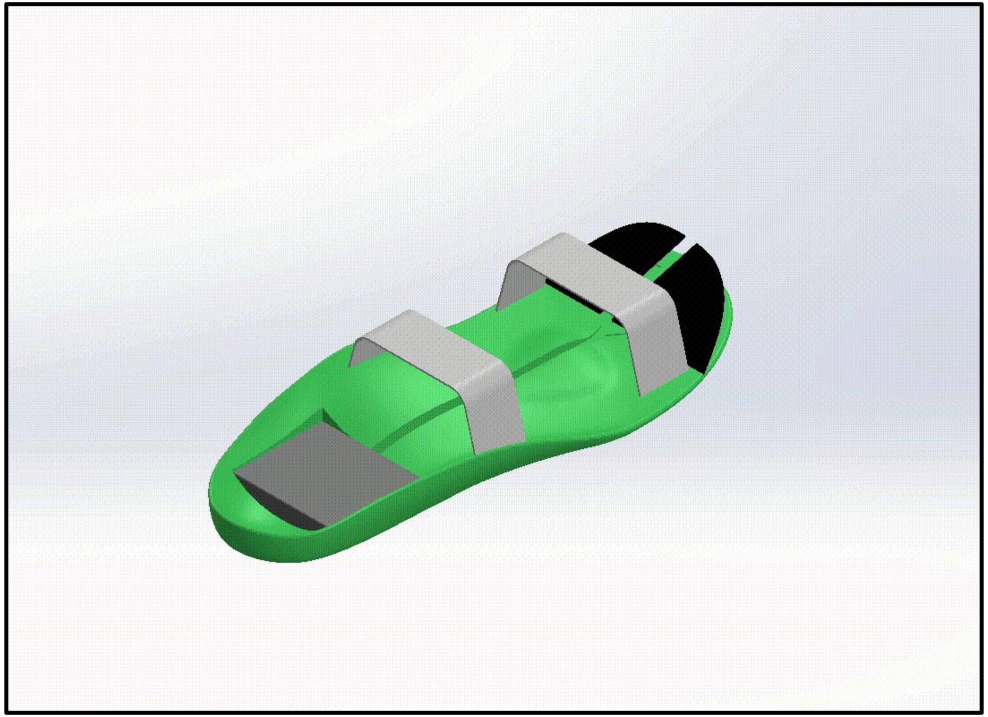


9th Cohort Design Goals and Objectives

- Redesign IMU fixture to improve output quality
- Improve ergonomics of foot controller layout
- Optimize neural network for gesture recognition
- Increase control method options of prosthetic

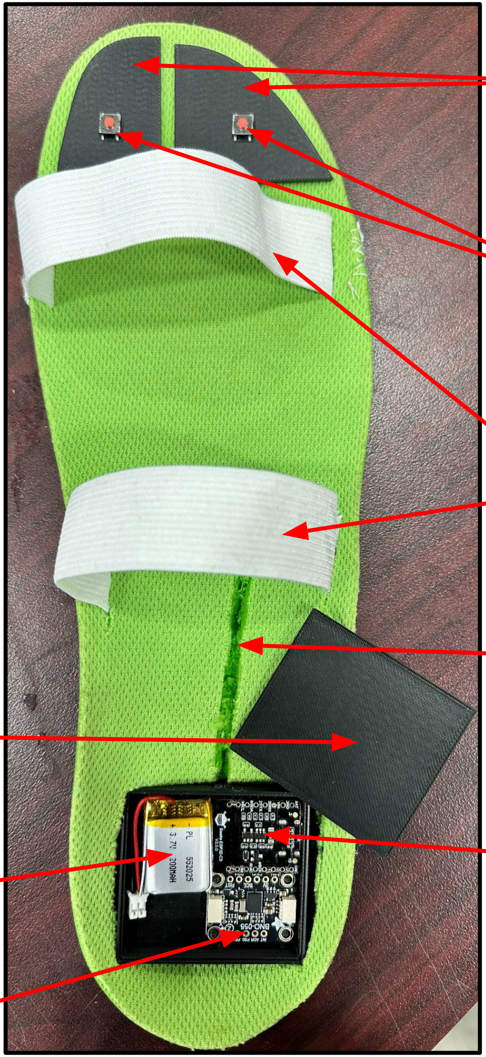
Foot Controller Redesign

- Relocated IMU for improved data
- Case: PC for high impact resistance, strength, durability, and thermal resistance
- Improved ergonomics
- Resized toe button flappers and relocated small toes button
- Elastic straps to make foot controller wearable barefoot

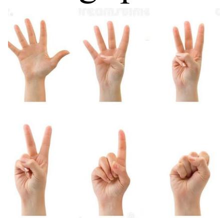


Foot Controller Redesign

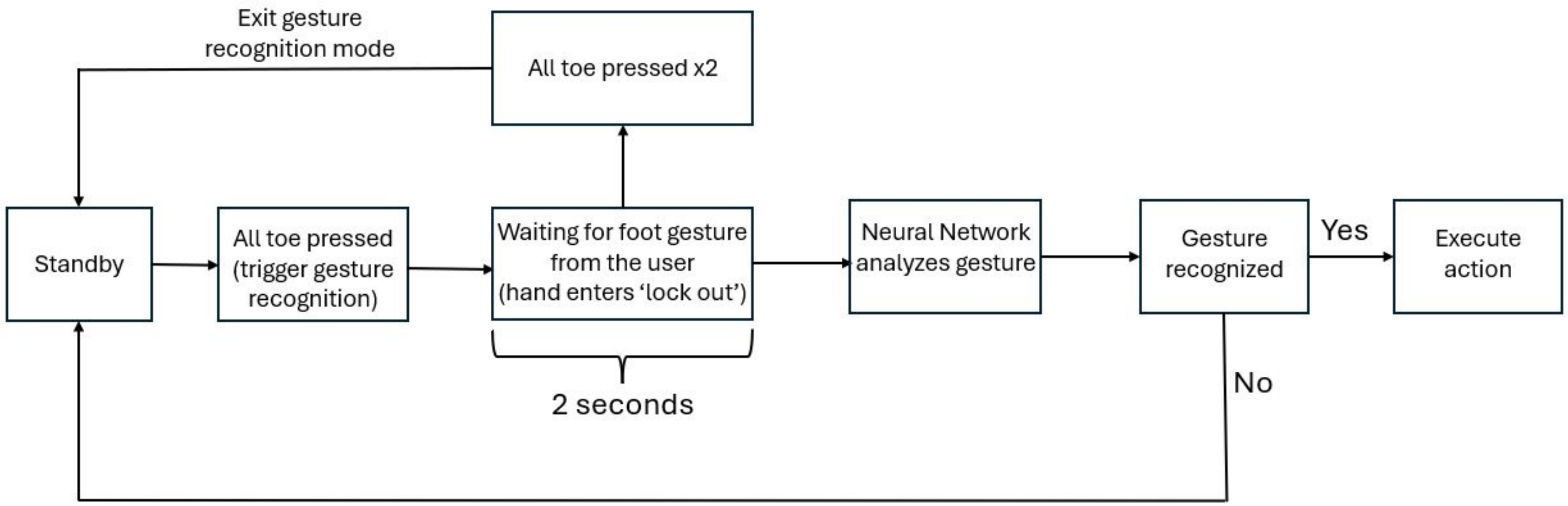
- Pros:
  - Improved IMU data
  - Robustness of insole
  - Intentional strengthening of battery housing and easier removal
- Cons:
  - Thickness of heel



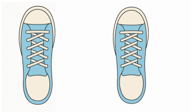
Buttons Function

Big toe press and hold 	Small toe press and hold 	All toe press 	Big toe press → small toe press 	Small toe press → big toe press 
Close hand gradually 	Open hand gradually 	**Trigger gesture recognition mode**	Cycle forward grip 	Cycle backward grip 

Gesture Recognition Mode

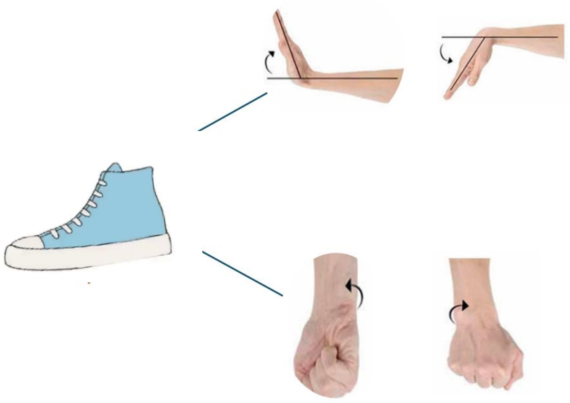


List of Gestures

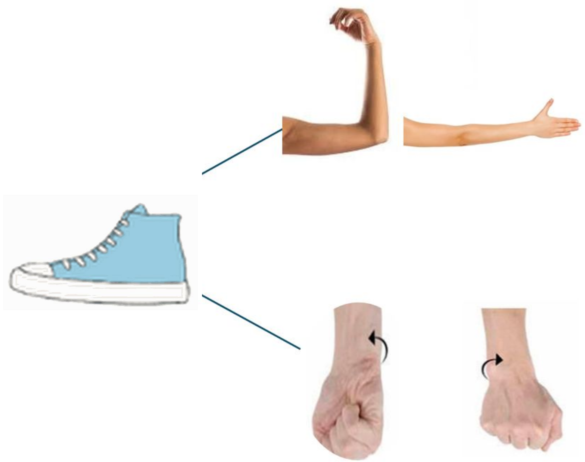
Toe tap		Wrist Actuation Mode
Flat tap		Elbow Actuation Mode
Heel tap		Shoulder Actuation Mode
Swipe left		Decrease servo motor speed
Swipe right		Increase servo motor speed
Heel click		Return to default

Animations made from real IMU readings

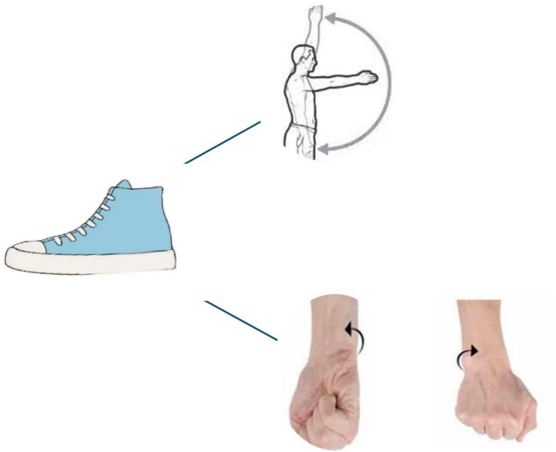
Actuation Modes



Wrist actuation mode



Elbow actuation mode

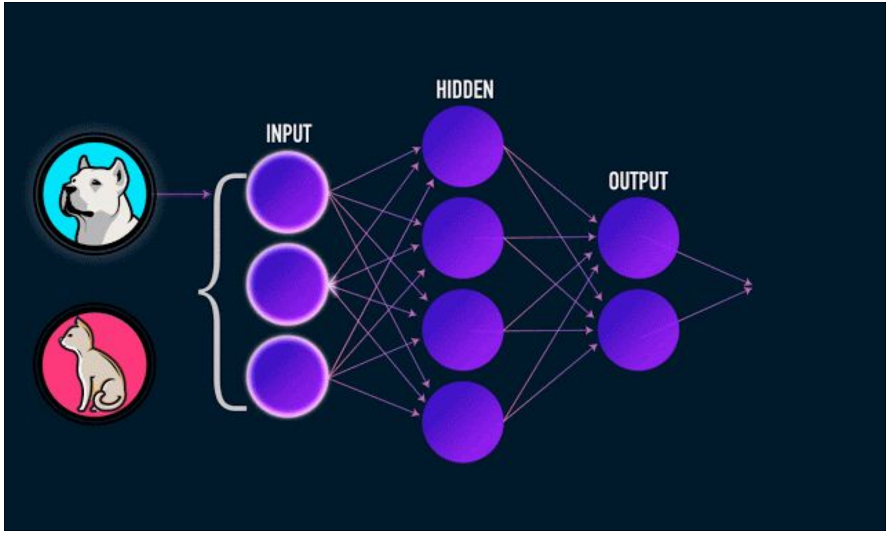


Shoulder actuation mode

Controlling the Arm Movement

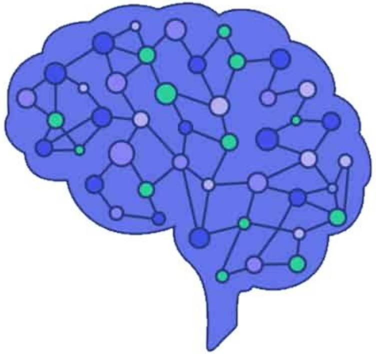
Foot motion	Ankle dorsiflexion 	Ankle plantarflexion 	Ankle inversion 	Ankle eversion 
Wrist actuation mode	Wrist extension 	Wrist flexion 	Wrist supination 	Wrist pronation 
Elbow actuation mode	Elbow flexion 	Elbow extension 	Wrist supination 	Wrist pronation 
Shoulder actuation mode	Shoulder flexion 	Shoulder extension 	Wrist supination 	Wrist pronation 

What is a Neural Network?

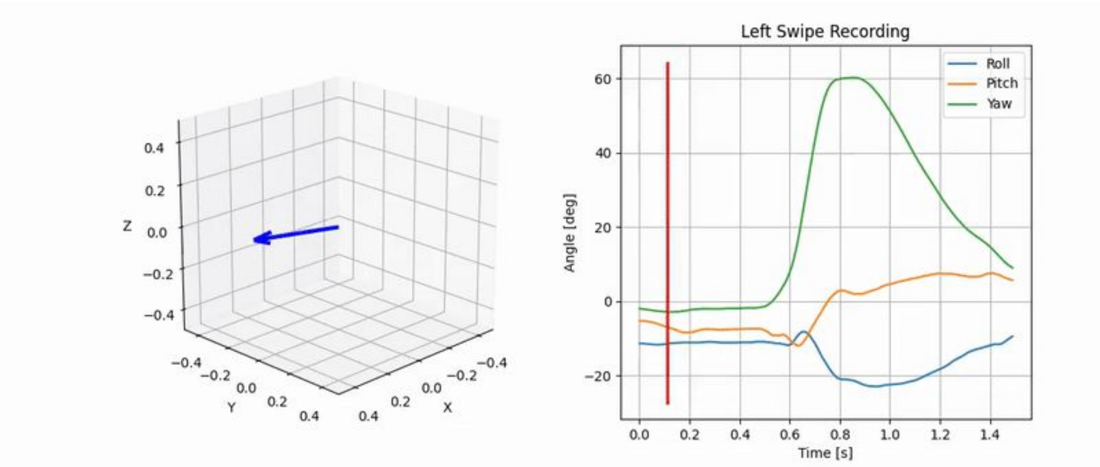


Neural Network Binary Classification
between Dog and Cat

A Neural Network is an algorithm that can be “trained” to recognize and classify patterns from data.



Neural Network for Gesture Recognition



Example of a "Left Swipe" Gesture IMU recording

Goal: Train a neural network to distinguish between all six gestures reliably in real time using IMU data as input.

Convolutional Neural Network (CNN)

Compared to a Feed Forward Neural Network:

Pros:

Requires Less Training Data

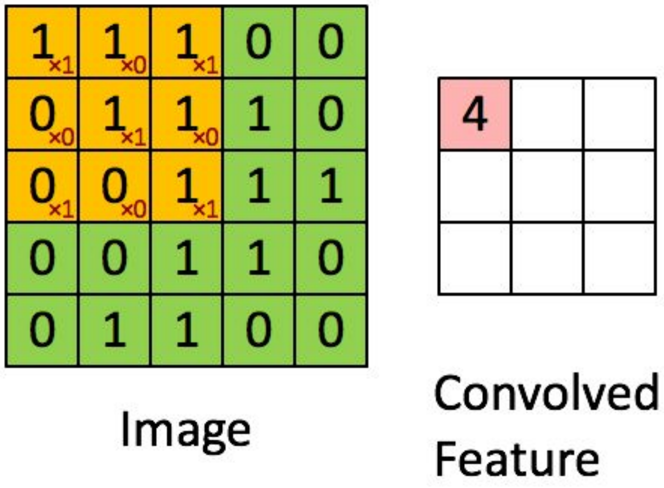
Accounts for Sequential or Time-Based Patterns

Multi-channel Input

Cons:

Higher Complexity in Setup

Computation Cost (TBD)



Convolution Operation Visualization

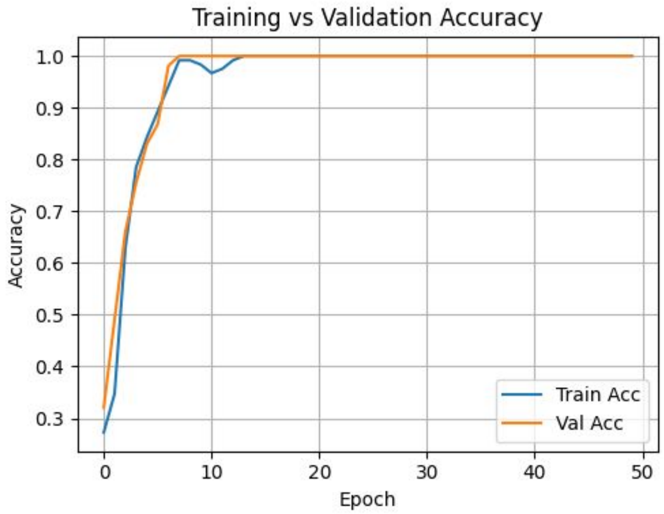
Preliminary Model Training

- As a test, we recorded a dataset containing only four distinct gestures

- After some tuning, the CNN model labeled all 174 samples with 100% accuracy.

- Average inference time is 58.44ms on a computer.

TensorFlow



Accuracy of Neural Network during Training

Tasks Before CDR

- Have a working prototype of the redesigned foot controller
- Test the Convolutional Neural Network model in real time
- Reduce redundancies and improve efficiency of arm and foot controller code

Haptic Feedback

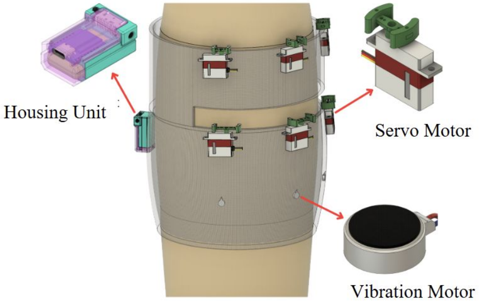
Team Members:

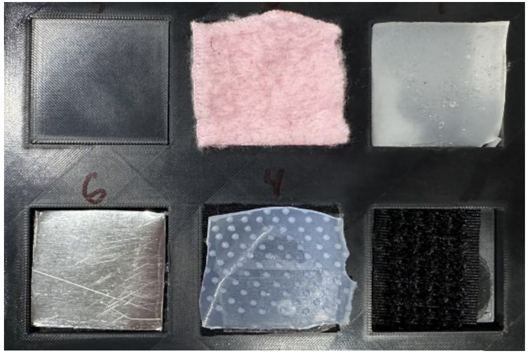
Jorge Alvarez, Nathan Handal, Chris Lopez, Vanessa Montejano

8th Cohort

- Motivation: Create noninvasive design for amputees who experience lack of sensory touch and can also serve as an addition to other prostheses in the market

- Design Overview
  - Used multiple servos to control texture application
  - Used a camera to detect different materials and applied closest material on upper arm
  - Electret microphone housed in a fingerprint-inspired case to pick up frequencies



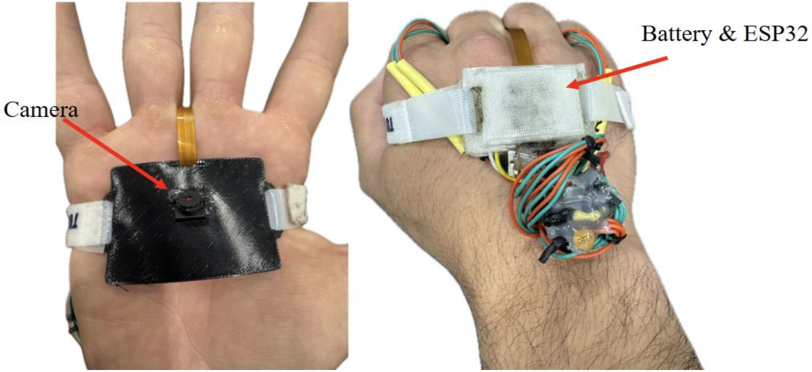


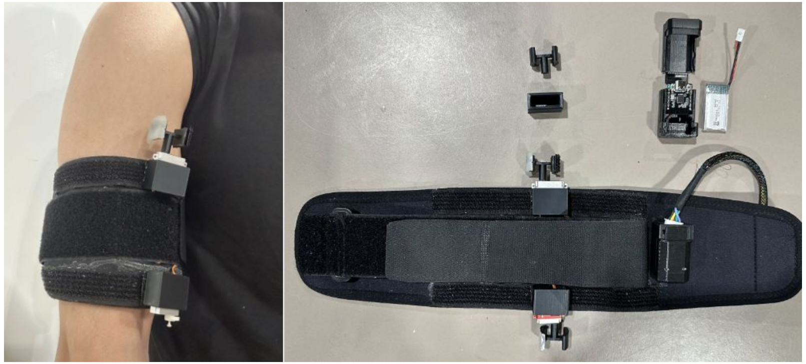
Joseph Sunbaty, Romel Melgar, and Jocelyn Camarena. *8th Cohort Haptic Feedback Report.* California State University, Northridge, Smart Prosthetics Senior Design Team, May 20, 2025.

8th Cohort

8th Cohort

- Limitations
  - Increased size
  - Wiring complexity
- Problems
  - Visual assistance of the materials was necessary for user to understand the material being applied
  - Unable to get camera to work so both systems weren't able to connect





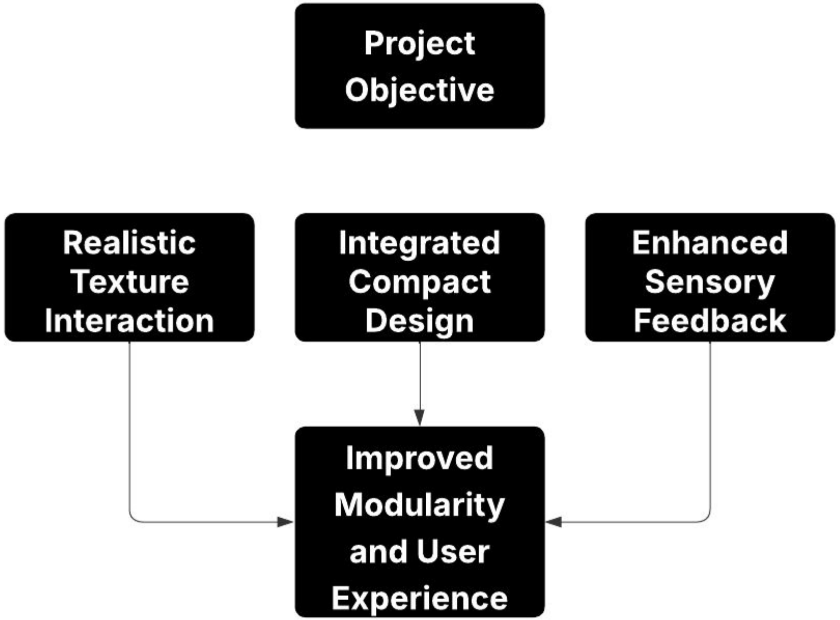
Goals and Improvements

- Goal
  - Develop compact sleeve capable of providing texture application with fewer components
- Improvements
  - Camera successfully works
  - Exoskeleton frame attaches directly to wearable robotic arm.
  - IR temperature sensors on fingertips for heat-based feedback.
  - Compact conveyor texture system replaces servo-based application.
  - BOA/Dial-based tightening system for quick, secure fit.
  - Fully detachable sleeve modules for maintenance and upgrades.
  - Enhanced vibration and thermal feedback synchronized with visual input.

8th Cohort vs Current Design Comparison		
Category	**8th Cohort Design (2024–2025)**	**Current Design (Your Team)**
System Overview	Two subsystems: Texture Identification (EchoPrint + camera) and Texture Application.	Integrated multi-sensor haptic feedback system with improved texture detection and real-time
Sensors & Microcontroller	SEEED XIAO ESP32-S3 with accelerometers and microphone; no temperature sensing.	SEEED XIAO ESP32-S3, accelerometers and IR temperature sensors on fingertips.
Texture Identification	EchoPrint system with electret microphone and camera for roughness and material detection.	Dual-sensor setup (optical + temperature) with accelerometer input for enhanced tactile and thermal mapping.
Texture Application	Servo motor-based armband applying interchangeable textures (Velcro, silicone, fabric, rubber, metal).	Compact conveyor belt system on the sleeve for texture delivery; modular and detachable
Wearable Design	Large silicone finger sacks, Velcro straps; non-detachable assembly.	Lightweight wearable sleeve with BOA tightening system for quick wear/removal; separate clip-on
Feedback Mechanism	Vibration and material contact on upper arm.	Vibration feedback plus temperature feedback for realistic touch
Form Factor	Bulky glove-style with embedded electronics and wiring.	Compact modular sleeve design with detachable components and integrated cable routing.
Software & AI Model	Edge Impulse grayscale model (~85% accuracy) for material classification.	TensorFlow Lite / Edge Impulse hybrid model with adaptive real-time learning.
Testing Results	57–69% tactile accuracy post-training; 84.9% visual classification accuracy.	In Progess

M.I.D.A.S. System Architecture

Hardware Development	AI Integration	System Testing & Validation
Glove and sleeve prototypes under fabrication and	CNN model training → TensorFlow Lite deployment	Thermal, vibration, texture trials to verify perception and



Core Hardware Components

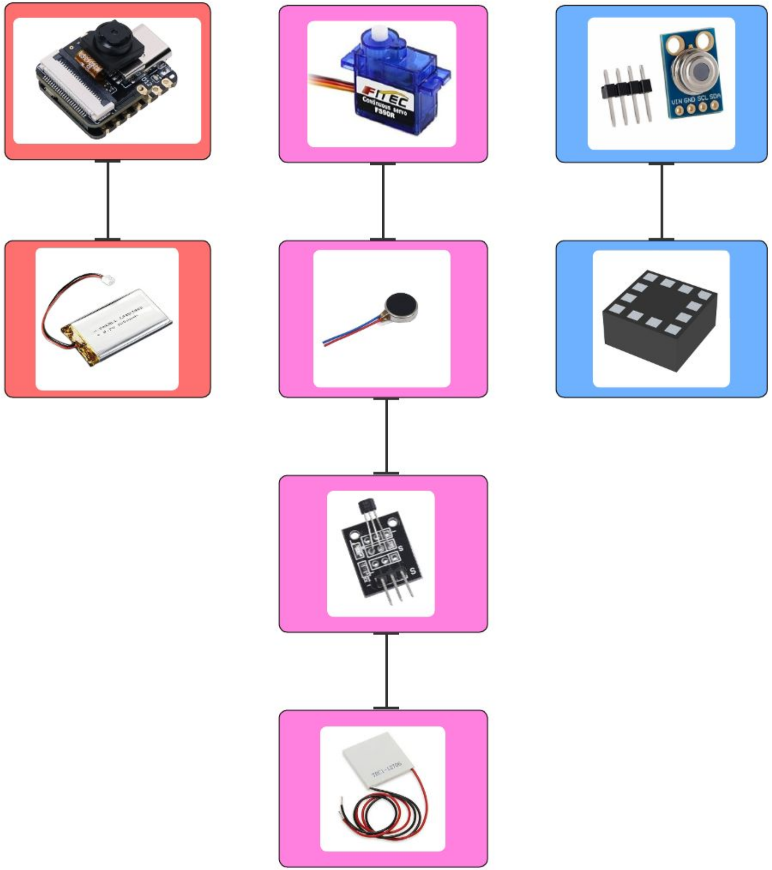


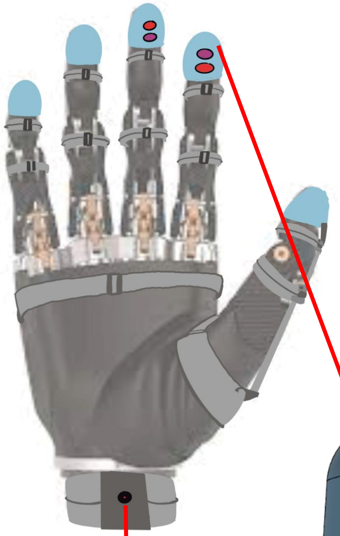
Diagram key

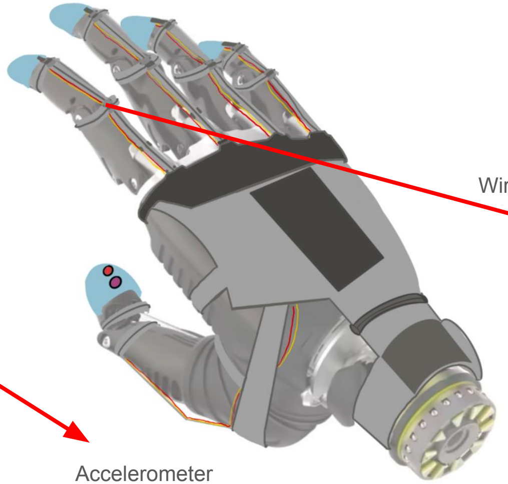
- Both Systems
- Sleeve
- Glove

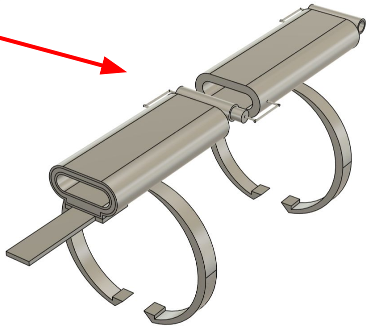
M.I.D.A.S. Gauntlet Subsystem

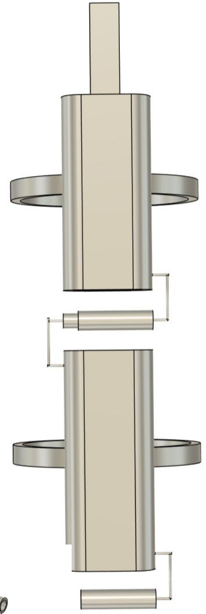
(Multimodal Integrated Detection and Stimulation)

Sensorized glove subsystem for material detection and data collection.



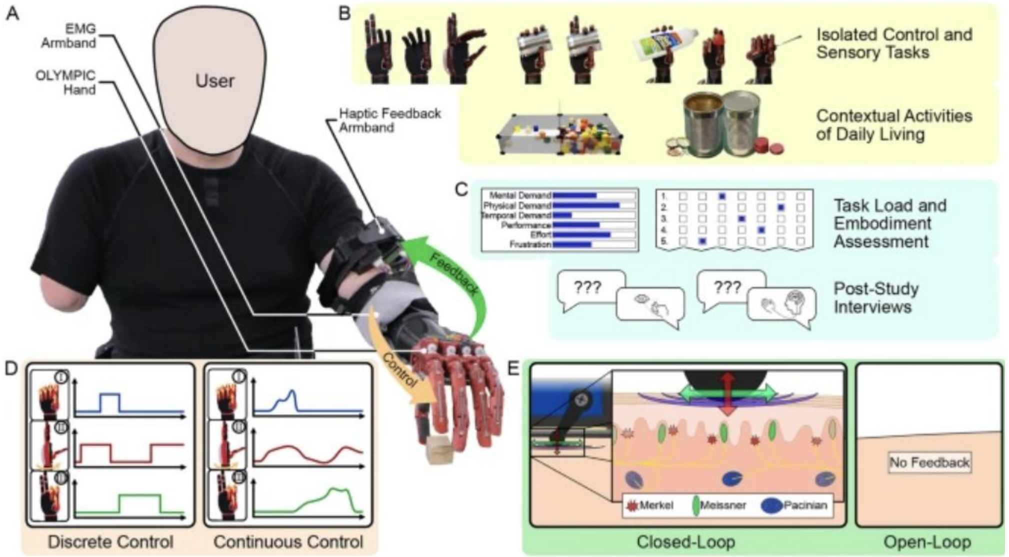






Haptic Feedback Armband

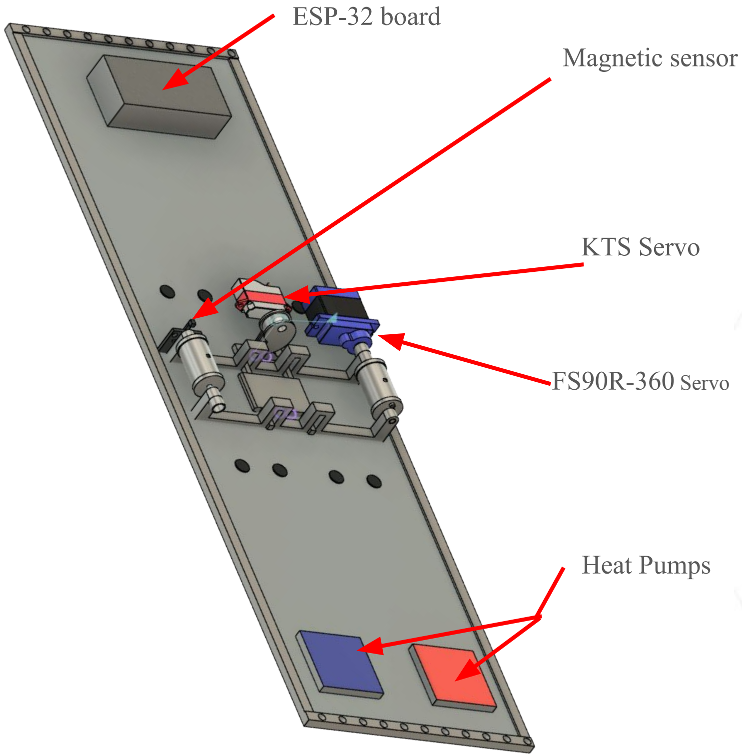
- Closed-loop control improves performance.
- Multimodal feedback enhances realism.
- Supports our system design.

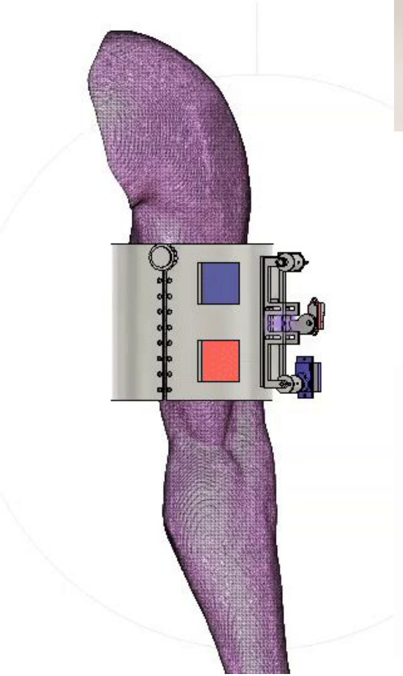


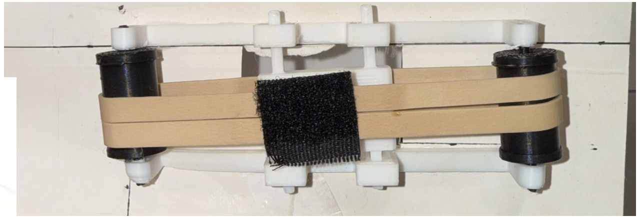
Chappell, D., Yang, Z., Clark, A.B. *et al.* Examining the physical and psychological effects of combining multimodal feedback with continuous control in prosthetic hands. *Sci Rep* 15, 3690 (2025). https://doi.org/10.1038/s41598-025-87048-x

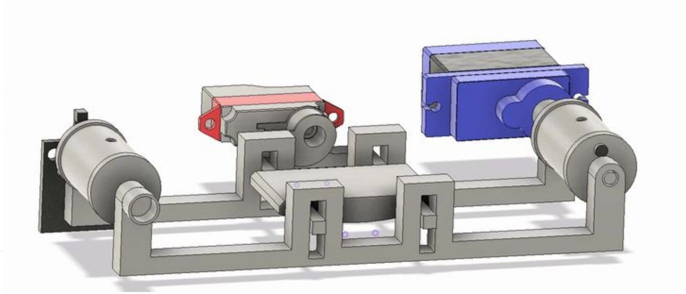
M.I.D.A.S Conduit Subsystem

Texture-application and multimodal feedback sleeve for upper-arm testing.









Electronics Architecture

Component	Subsystem	Function	Voltage / Current Specs
Seeed XIAO ESP32-S3 Sense	Both	Main controller, Wi-Fi, ML inference	5 V in / 3.3 V logic / < 250 mA
MXC6655XA (Vibrational sensor)	Glove	Motion Sensing	1.62 - 3.6 V / < 0.3 mA
Thermal Camera Module	Glove	Thermal Detection	5 V / ~150 mA
TEC1-12706 (T.E. H/C Pump)	Sleeve	Heating / cooling actuator	12 V / 6 A max
Vibration Motors	Sleeve	Vibrotactile feedback	3 V / 75 mA each
FEETECH Servo	Sleeve	Texture applicator motion	5 V / 0.8 A stall
Magnetic Sensor	Sleeve	Position Feedback	5 V / < 20 mA
Li-Po Battery	Both	Power supply (3.7 V / 2000 mAh)	Boosted to 12 V and 5 V rails

- Power budget assumes 85 % from the DC-DC step-up regulators supplying 12 V and 5 V rails.
- TEC1-12706 current limited to ≤ 1.5 A to maintain safe operation and realistic runtime.
- Both glove and sleeve powered by independent 3.7 V / 2000 mAh Li-Po packs.

$$P_{Sleeve} = (12V)(1.5A)+(5V)(0.8A)+(3V)(0.075A\times4)$$

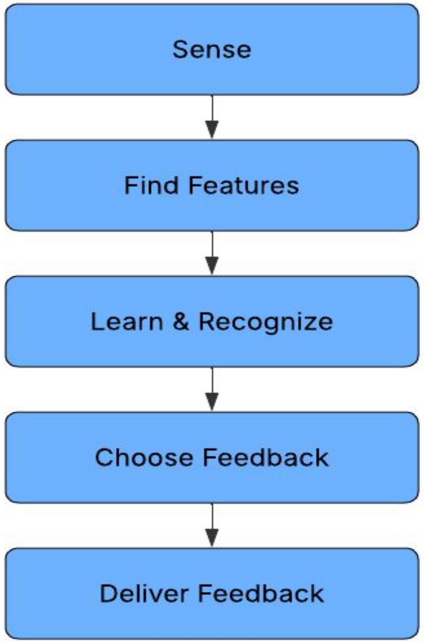
$$P_{Sleeve} = 21W$$

$$I_{battery} = \frac{P_{sleeve}}{\eta * V_{battery}} = \frac{21}{0.85*3.7} = 6.52A$$

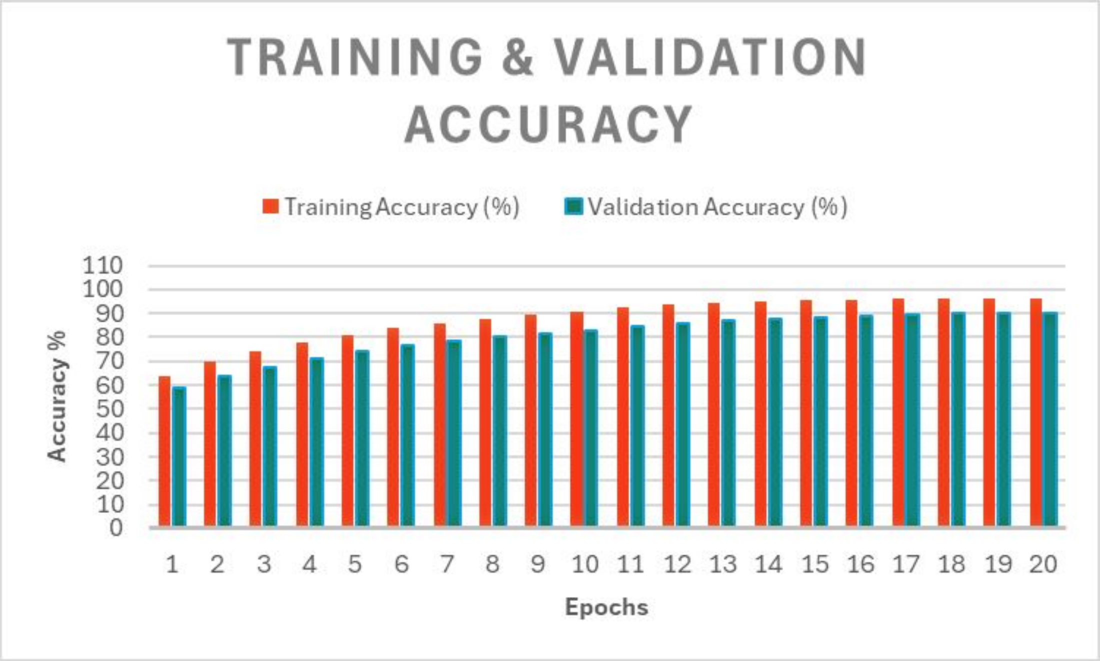
$$t_{runtime} = \frac{2Ah}{6.52A} = 0.31h$$

$$t_{runtime} = 0.31h * \frac{60mins}{1h} = 18.6min$$

TensorFlow Implementation



Simulates how accuracy improves as the model learns.



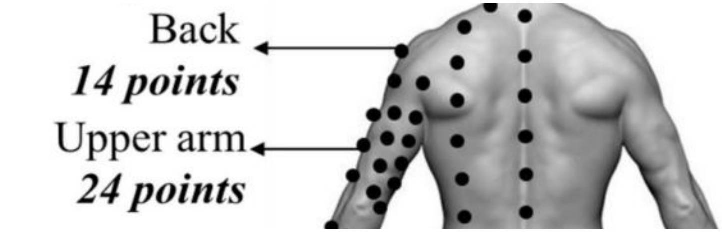

```
epochs = np.arange(1, 31)
train_acc = 0.6 + 0.4*(1 - np.exp(-0.15*epochs))
val_acc   = 0.55 + 0.38*(1 - np.exp(-0.12*epochs))
plt.plot(epochs, train_acc*100, label='Train')
plt.plot(epochs, val_acc*100, label='Validation')
```

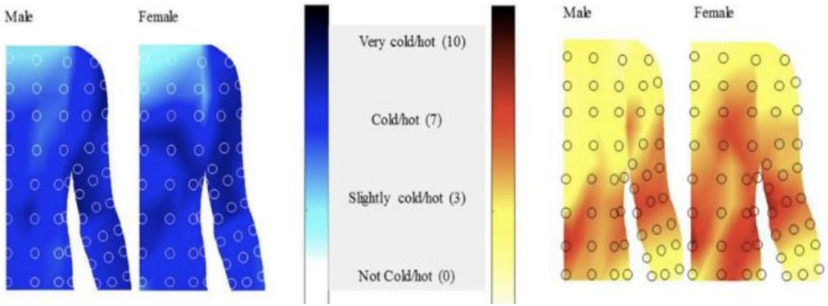
Experimental Validation Plan

Purpose: Train participants to distinguish textures through touch and vision to simulate haptic feedback for the prosthetic arm

How: Controlled stimuli (temperature, vibration, and texture) applied to mapped skin regions using the Conduit Sleeve system. Participant responses recorded to evaluate perception accuracy and comfort

Why: Understanding how humans integrate touch and vision to distinguish textures supports the design of prosthetic systems that provide natural, intuitive haptic feedback for improved control and embodiment





Maohui Luo, Zhe Wang, Hui Zhang, Edward Arens, Davide Filingeri, Ling Jin, Ali Ghahramani, Wenhua Chen, Yingdong He, Binghui Si, High-density thermal sensitivity maps of the human body, Building and Environment, Volume 167,2020,106435,ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2019.106435

Future Iterations & Path Forward

- Will work on connecting vibration sensors as well as the thermal sensors for the sleeve
- Create prototype for the texture application conveyer belt with servos and textures
- Begin training to gather data on best spot for texture identification
- Improving battery life
- Figuring out cold temperature application

9th Cohort Calendar

- Team Invites: June 6th, 2025
- Research Papers: August 30th, 2025
- NBC Interview: September 2nd, 2025
- PDR: October 22nd, 2025
- CDR: November 26th, 2025
- Cal State Biotech Fair: January 24th, 2026
- Report: March 22nd, 2026
- CSUN Posium: April 2026
- CSUN Showcase: May 2025

Thank you!
Any Questions?

CSUN | CALIFORNIA STATE UNIVERSITY NORTHRIDGE