EchoSign - Final

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EchoSign - Introduction and Use cases

- **Problem:** Deaf people often struggle to communicate with non-deaf speakers

- **Solution:** Pair of gloves that translate sign language to audible English

Deaf/HH Population: **11 Million**
About **1 Million** Profoundly Deaf

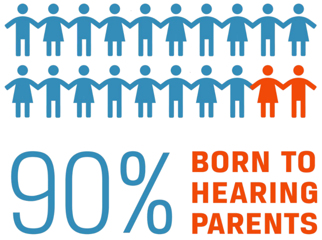
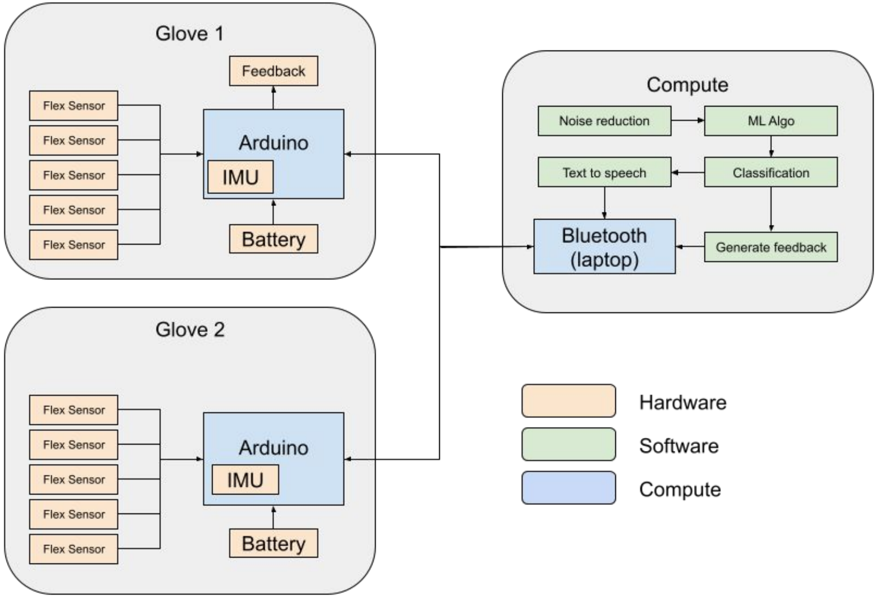


Image from BYU

Qualitative Requirements	Use Case Requirement
Maintain normal signing **speed**	.5 second latency
Glove should be **reliable**	85% sign prediction accuracy
Portable and can withstand daily activity	100g weight limit per glove
Chosen words **represent** ASL vocabulary	10 of most frequently signed double-handed ASL words

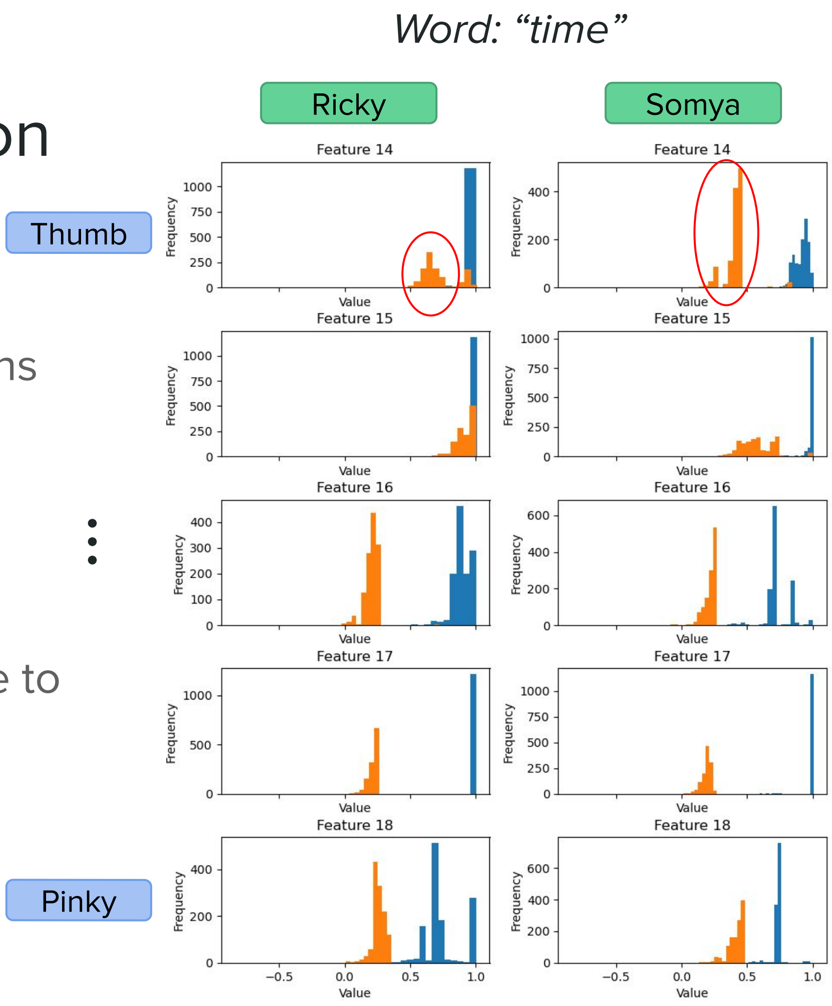
Solution Approach

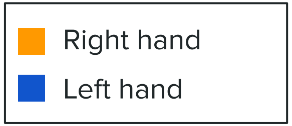
- Two battery-powered gloves with sign-to-speech capability over BT
- Design Updates:
  - Got rid of speaker
  - Added PCB
  - Using two ML models (different subsets of the chosen words)
- Bluetooth
  - Python - SimplePyBLE
  - Arduino BLE - Native libraries
- ML
  - Neural Network
  - Two models, two layers, 128 nodes



Solution Approach: Data Collection

- Process details: peripheral setup phase, movement to introduce variation in the data
- 3 people x (1200 data vectors / sign) x (11 signs / person) ≈ 39600 data vectors
- Collection via USB vs. Bluetooth
- Manual inspection and verification of sensor data via feature plots (see right figure)
- Noise Reduction Algorithm: calibration phase to normalize flex sensor data





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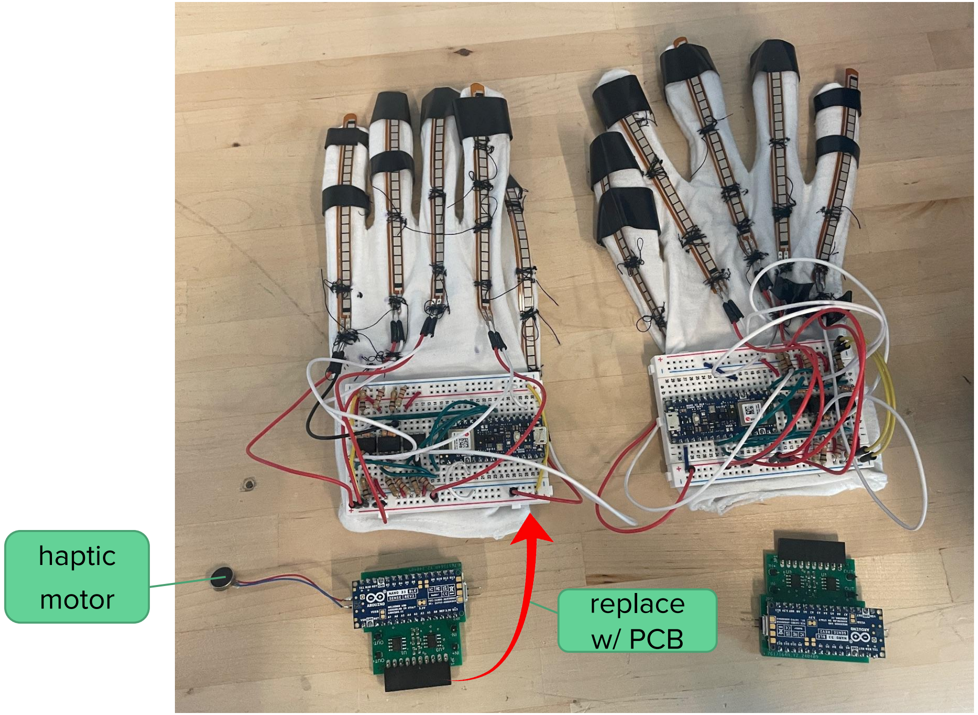
Complete Solution

- 11 signs (10 double-handed, one ‘no sign’ state)
- Wireless capability

Category	**Double-handed ASL Words**
pronoun	*what*
noun	*time, car, church, family*
verb	*meet, live*
adjective	*big*
adverb	*more, but*

From “*DeepASL*: Enabling … Sentence-Level Sign Language Translation” by B. Fang, J. Co, M. Zhang, 2017



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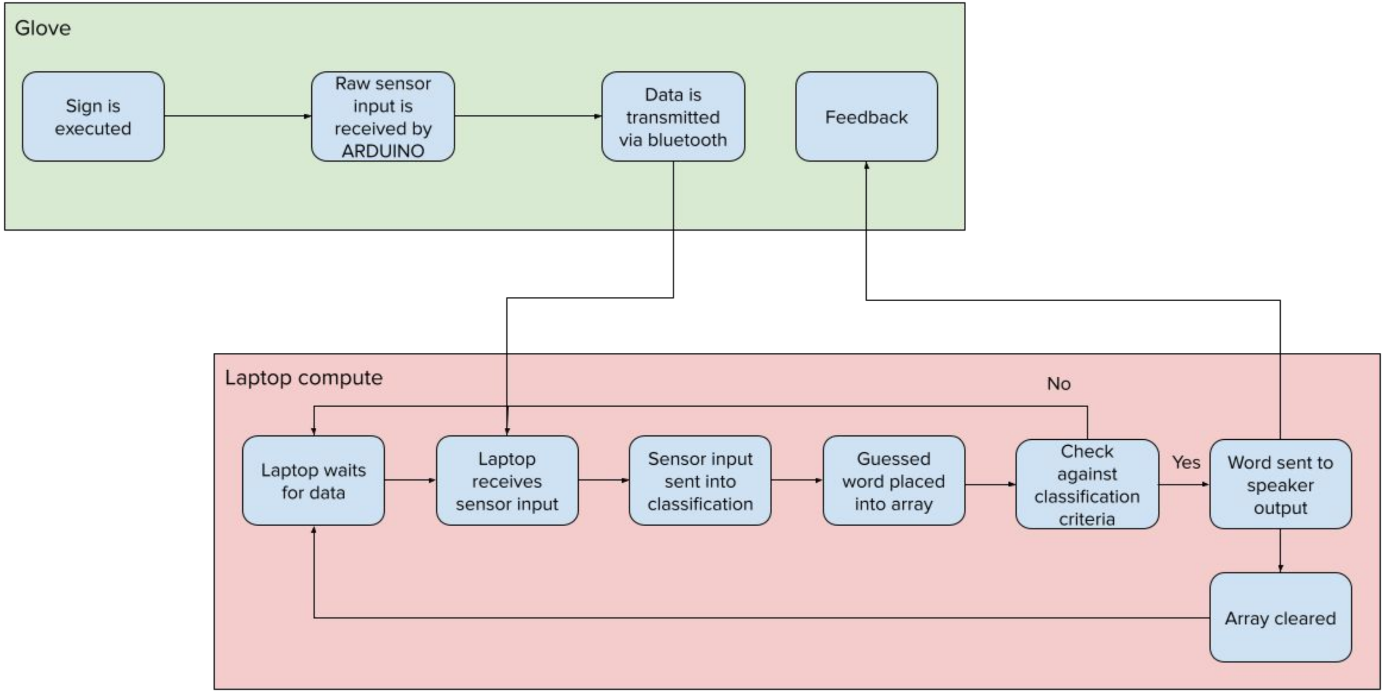
Design Requirements/Testing - ML Model

Requirement	Testing	Metrics
Accuracy	• Data split into train/test split • Performance of NN evaluated on test set	• Two layered architecture achieved test accuracy of 97% • Req (> 90%)
Latency	• Python timing module to compute average speed	• Model takes an infinitesimal amount of time to compute • Req (< 50ms)
Accuracy (Real-Time)	• User wears glove and signs a predetermined set of vocabulary • Each word ~10 times	• Testing reveals that the model performs well on 10/11 of vocab • Overall accuracy of 89%

Design Trade-offs - ML

Issue	Trade-offs	Final Choice
Classification heuristic length - Number of consecutive ML output before speaker output	● Length of 8 is more robust to noise, latency 2 sec ● Length of 2 is more sensitive to noise, latency 0.4 sec	● Length of 4 balances both accuracy without sacrificing too much in latency
Model Complexity - ● Number of nodes/layers ● Number of models	● Increased model complexity ○ Potential performance boost ○ Increase in latency ○ More training data required ○ Risk of overfitting	● Two fully connected layers of 128 nodes ● Two models for subsets of data ● Balances performance, latency, and data requirements

Sign to speech pipeline

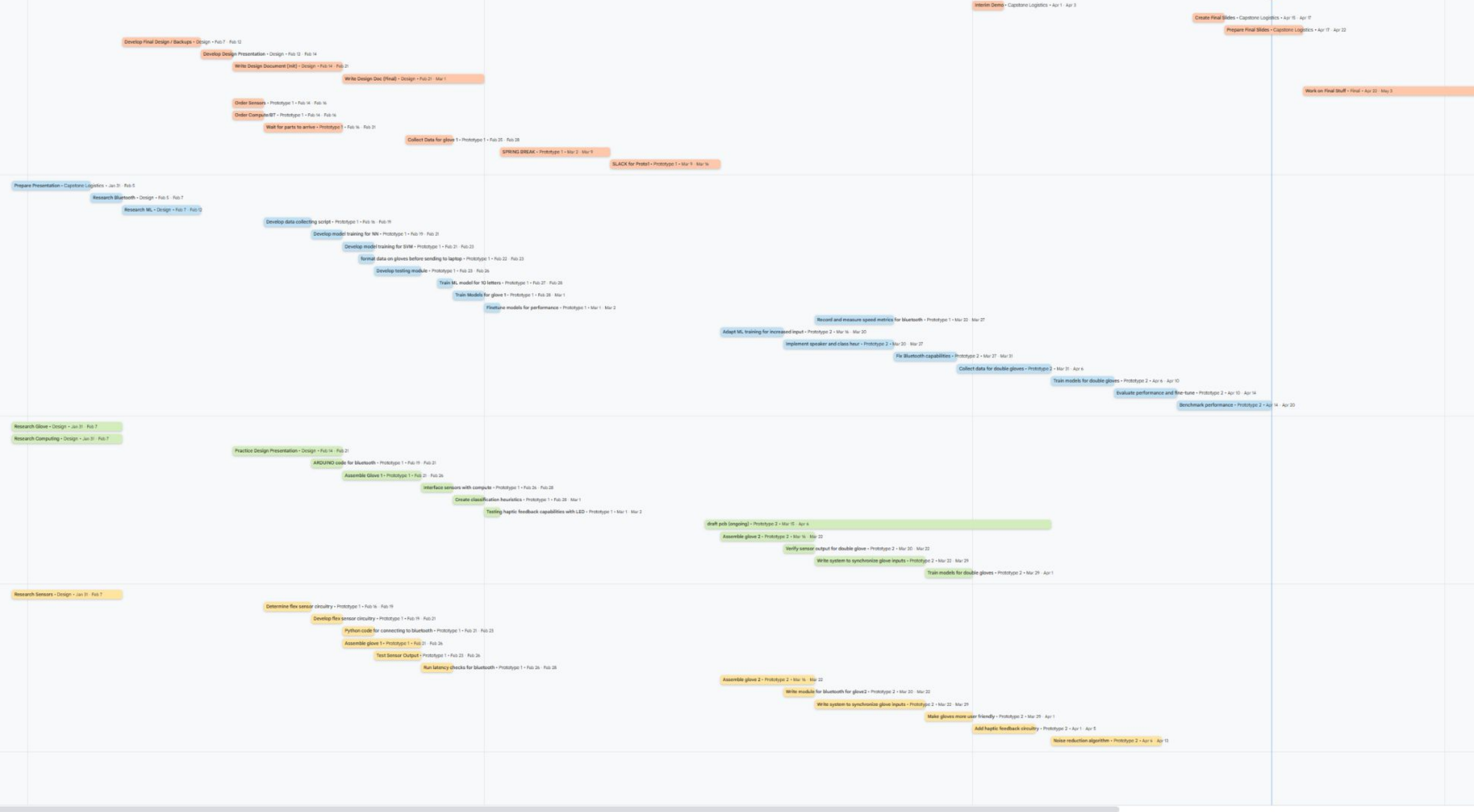


Design Tradeoffs - General

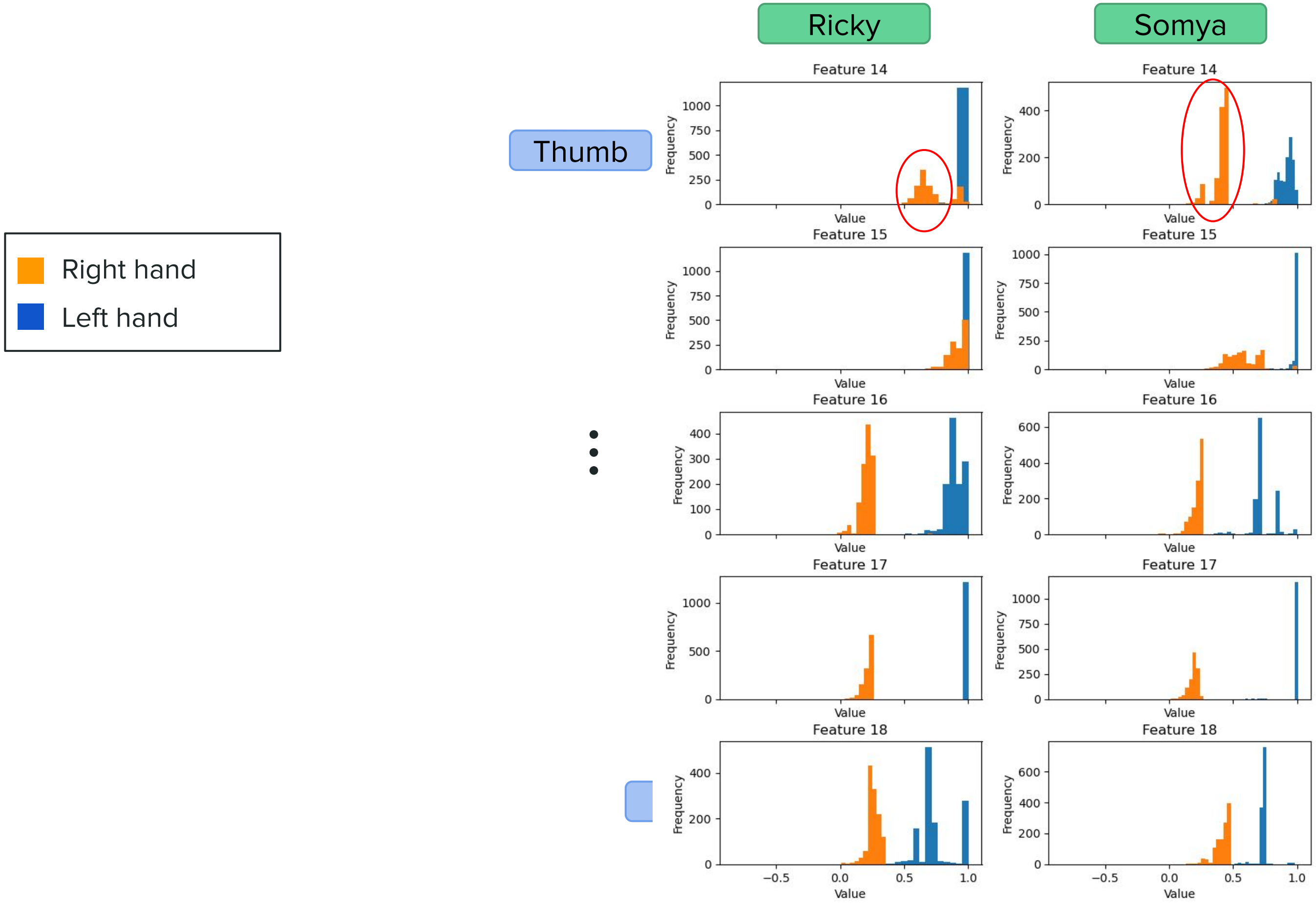
Issue	Trade-offs	Final Choice
Distinguishment of letters that rely on touch	Classification power vs. usability	Omission of touch sensors
Normalizing data discrepancies between different users	Overhead vs. usability	Added calibration phase
On-glove speaker not possible with modules compatible with chosen compute unit	Portability vs. robustness	Speech outputted through laptop
Powering the Arduino Nano wirelessly	Compact and lightweight design vs. battery lifetime	Use two 3.7V LiPo batteries in series at 500mAh
Design was bulky and not secure	Simplicity and flexibility vs. clean design	Printed custom PCB and 3D printed case with velcro strap

Overall - Testing, Verification, Validation

Requirement	Verification	Metrics
Accuracy	• Evaluate accuracy on separate test data • Evaluate accuracy on real-time performance	• NN has **97%** accuracy on test set • Real-time accuracy of **89%** (> 85%)
Latency	• Evaluate time for ML prediction • Timing from first sensor reception → speaker output	• NN has infinitesimal time for prediction • Real-time prediction duration: **0.6-0.7 sec** (~0.5 sec)
Vocabulary	• Classification on ten ASL words over multiple POS (noun, verb, adjective, etc.)	• Classification works well on **10/11 signs**


Interim Demo • Capstone Logistics • Apr 1 · Apr 3
Create Final Slides • Capstone Logistics • Apr 15 · Apr 17
Prepare Final Slides • Capstone Logistics • Apr 17 · Apr 22
Develop Final Design / Backups • Design • Feb 7 · Feb 12
Develop Design Presentation • Design • Feb 12 · Feb 14
Write Design Document (init) • Design • Feb 14 · Feb 21
Write Design Doc (Final) • Design • Feb 21 · Mar 1
Work on Final Stuff • Final • Apr 22 · May 3
Order Sensors • Prototype 1 • Feb 14 · Feb 16
Order Compute/BT • Prototype 1 • Feb 14 · Feb 16
Wait for parts to arrive • Prototype 1 • Feb 16 · Feb 21
Collect Data for glove 1 • Prototype 1 • Feb 25 · Feb 28
SPRING BREAK • Prototype 1 • Mar 2 · Mar 9
SLACK for Proto1 • Prototype 1 • Mar 9 · Mar 16
Prepare Presentation • Capstone Logistics • Jan 31 · Feb 5
Research Bluetooth • Design • Feb 5 · Feb 7
Research ML • Design • Feb 7 · Feb 12
Develop data collecting script • Prototype 1 • Feb 16 · Feb 19
Develop model training for NN • Prototype 1 • Feb 19 · Feb 21
Develop model training for SVM • Prototype 1 • Feb 21 · Feb 23
format data on gloves before sending to laptop • Prototype 1 • Feb 22 · Feb 23
Develop testing module • Prototype 1 • Feb 23 · Feb 26
Train ML model for 10 letters • Prototype 1 • Feb 27 · Feb 28
Train Models for glove 1 • Prototype 1 • Feb 28 · Mar 1
Finetune models for performance • Prototype 1 • Mar 1 · Mar 2
Record and measure speed metrics for bluetooth • Prototype 1 • Mar 22 · Mar 27
Adapt ML training for increased input • Prototype 2 • Mar 16 · Mar 20
Implement speaker and class heur • Prototype 2 • Mar 20 · Mar 27
Fix Bluetooth capabilities • Prototype 2 • Mar 27 · Mar 31
Collect data for double gloves • Prototype 2 • Mar 31 · Apr 6
Train models for double gloves • Prototype 2 • Apr 6 · Apr 10
Evaluate performance and fine-tune • Prototype 2 • Apr 10 · Apr 14
Benchmark performance • Prototype 2 • Apr 14 · Apr 20
Research Glove • Design • Jan 31 · Feb 7
Research Computing • Design • Jan 31 · Feb 7
Practice Design Presentation • Design • Feb 14 · Feb 21
ARDUINO code for bluetooth • Prototype 1 • Feb 19 · Feb 21
Assemble Glove 1 • Prototype 1 • Feb 21 · Feb 26
interface sensors with compute • Prototype 1 • Feb 26 · Feb 28
Create classification heuristics • Prototype 1 • Feb 28 · Mar 1
Testing haptic feedback capabilities with LED • Prototype 1 • Mar 1 · Mar 2
draft pcb (ongoing) • Prototype 2 • Mar 15 · Apr 6
Assemble glove 2 • Prototype 2 • Mar 16 · Mar 22
Verify sensor output for double glove • Prototype 2 • Mar 20 · Mar 22
Write system to synchronize glove inputs • Prototype 2 • Mar 22 · Mar 29
Train models for double gloves • Prototype 2 • Mar 29 · Apr 1
Research Sensors • Design • Jan 31 · Feb 7
Determine flex sensor circuitry • Prototype 1 • Feb 16 · Feb 19
Develop flex sensor circuitry • Prototype 1 • Feb 19 · Feb 21
Python code for connecting to bluetooth • Prototype 1 • Feb 21 · Feb 23
Assemble glove 1 • Prototype 1 • Feb 21 · Feb 26
Test Sensor Output • Prototype 1 • Feb 23 · Feb 26
Run latency checks for bluetooth • Prototype 1 • Feb 26 · Feb 28
Assemble glove 2 • Prototype 2 • Mar 16 · Mar 22
Write module for bluetooth for glove2 • Prototype 2 • Mar 20 · Mar 22
Write system to synchronize glove inputs • Prototype 2 • Mar 22 · Mar 29
Make gloves more user friendly • Prototype 2 • Mar 29 · Apr 1
Add haptic feedback circuitry • Prototype 2 • Apr 1 · Apr 5
Noise reduction algorithm • Prototype 2 • Apr 6 · Apr 13

Word: "time"


Right hand
Left hand
Ricky
Somya
Thumb
Feature 14
Feature 15
Feature 16
Feature 17
Feature 18
Frequency
Value
−0.5
0.0
0.5
1.0