



# CareLink Pill Box Project

## Hypertension Medication Tracking

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<https://github.com/mariyang/T-Mobile-Carelink-515-Projects/tree/carelink-pillbox-project>

# The Problem

## Context

Globally, hypertension affects over 1 billion people, yet **poor medication adherence (30-40%) remains a major barrier to effective treatment**, leading to serious health risks and increased healthcare costs. The most prevalent reasons include: forgetfulness, failure to perceive the need for medication, fear of side effects and low self-efficacy.

## Problem

Despite the scope of the problem, patients and caregivers still lack intuitive, connected tools to track medication in relation to blood pressure and remain engaged with their care plans.

## Unmet Need

An integrated hardware and software solution that leverages T-Mobile's connectivity to enable real-time tracking, reminders, and data sharing - empowering patients, reducing caregiver burden and improving health outcomes.



# Our Solution

A two-part system to track medication adherence and support hypertension care:

## 1. Detecting Pill Removal by Photoresistors

- Embedded under each separated box of the pill box, when the pills are removed, the photoresistor will return a lower value as more light is absorbed.

## 2. Verifying Pill Consumption with Camera

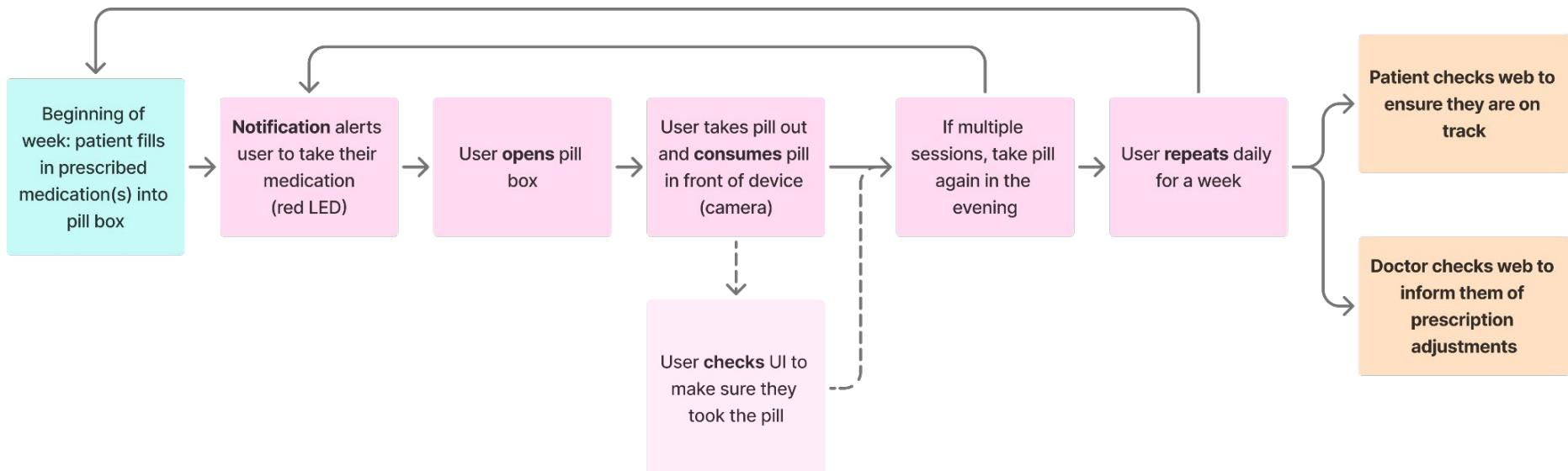
- A camera tracks gesture to monitors the consumption.
- ML image detection ensures that ingestion (not just removal) is verified.

**Patient & Doctor portals (health data tracking):** All data is synced to a companion portal, allowing both patients and doctors to track medication adherence over time

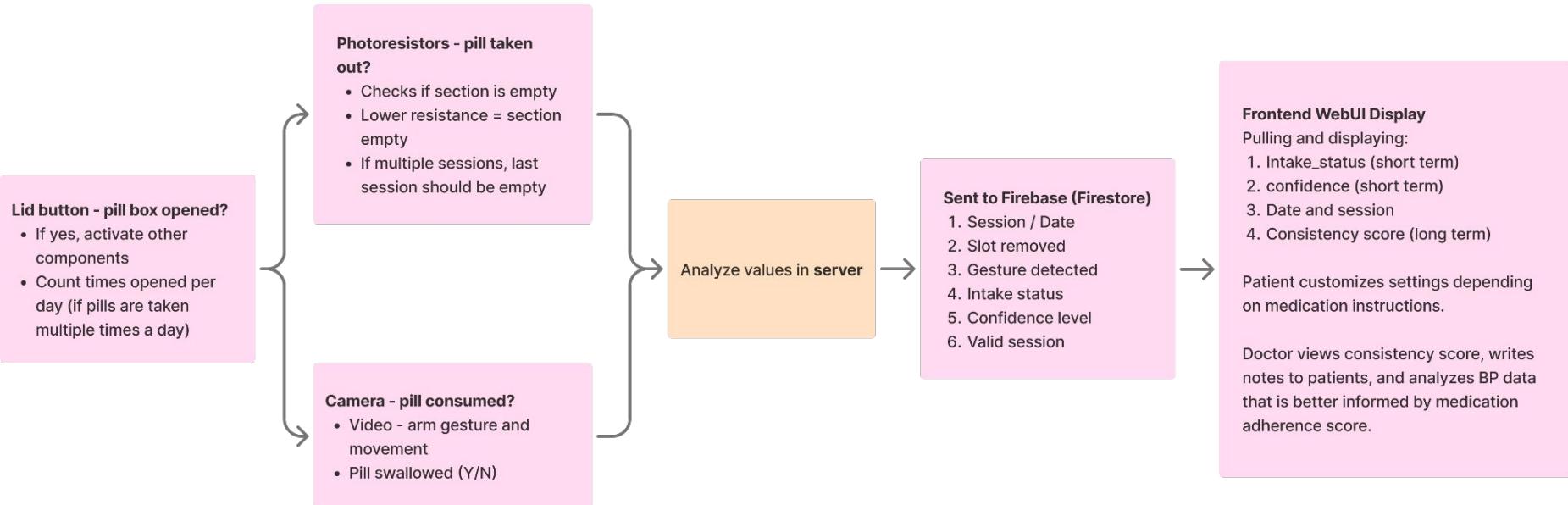
**T-mobile 5G Connection:** The device connects to the cloud through T-Mobile's 5G network, which supports real-time data upload and remote monitoring without depending on local Wi-Fi.



# User Flow Diagram



# Data Pipeline



# Enclosure Design

We designed a weekly-use pill box with a compact, square-shaped form, making it suitable for daily use at home or easy to carry on the go.

The system is activated when the lid is opened. Inside, there are seven compartments to hold a week's medication. Each compartment is equipped with a photoresistor at the bottom to detect whether the pill has been taken.

On the top-right corner of the lid, a small camera is embedded to verify whether the user has actually swallowed the pill. A mirror is positioned next to the camera to help users align themselves properly within the frame.

At the bottom of the device, two LED indicators provide visual feedback: a red LED reminds users to take their medication on time; a white LEDs to notify if all pills are removed or the week is over.



# Enclosure Design - Iterations



# Prototype Components: Photoresistors

Our system uses an ESP32 microcontroller connected to **seven photoresistors (LDRs)**, each positioned under an individual pill slot.

## Data Flow:

**ESP32 Sensors → EMA Filtering → Flask Server → Firebase**

## Hardware Components:

- 7 LDR (Light Dependent Resistor) sensors for pill detection
- Button control (GPIO44) for system on/off
- WiFi connectivity for cloud communication

## Smart Detection System:

- Exponential Moving Average (EMA) filtering for stable readings
- Configurable thresholds per sensor slot

```
confidence: "High"
gesture_count: 1
gesture_detected: true
gesture_timestamp: 1748917053
intake_status: "Taken"
last_updated: June 2, 2025 at 7:17:47 PM UTC-7
ldr_timestamp: 1748917053
person_in_frame: true
pills_present: 4
pills_removed: 3
removed_slots
  0 2
```

# Prototype Components: Camera

The camera component is directly connected to the PCB for power + button signal.

Releasing the button activates the camera to collect 50 frames (10 FPS) after a 3 second delay. These 50 frames are sent to the flask server to be analyzed.

## Data Flow:

**ESP32 Cam → Flask Server → Firebase**

### Gesture Detection:

- On the flask server, we use MediaPipe to detect poses.
- These are then analyzed to determine whether gesture has been made.
- **Savitzky-Golay low-pass filter** is applied for cleaner signals.

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person\_in\_frame: true

pills\_present: 4

pills\_removed: 3

removed\_slots

# Data Sent to Firestore

```
# Compute intake status
if pills_removed is None:
    intake_status = "Not enough data"
    confidence = "Low"

elif pills_removed > 0:
    intake_status = "Taken"
    confidence = "High"

elif pills_removed == 0 and session_valid:
    intake_status = "Uncertain"
    confidence = "Medium"

elif pills_removed == 0 and not session_valid:
    intake_status = "Not Taken"
    confidence = "High"

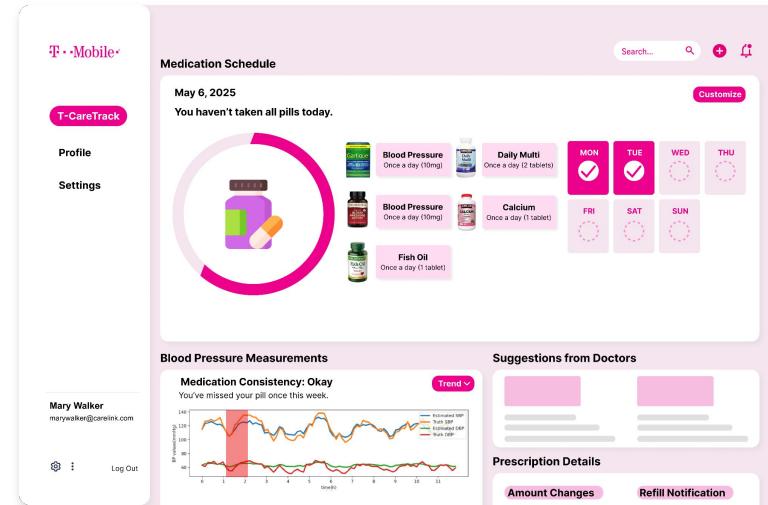
else:
    intake_status = "Unknown"
    confidence = "Low"
```

```
confidence: "High"
gesture_count: 1
gesture_detected: true
gesture_timestamp: 1748917053
intake_status: "Taken"
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# UI Design

## 1. Medication Schedule

- Accounts for types of medications, frequency, and when they need to be taken.
- “Customize” button - for if the prescription changes.



## 2. Blood pressure measurements

## 3. Hypertension progress

- Medication consistency status
- Missed medication highlighted over BP trend visualization
- Tab to toggle week, month, year

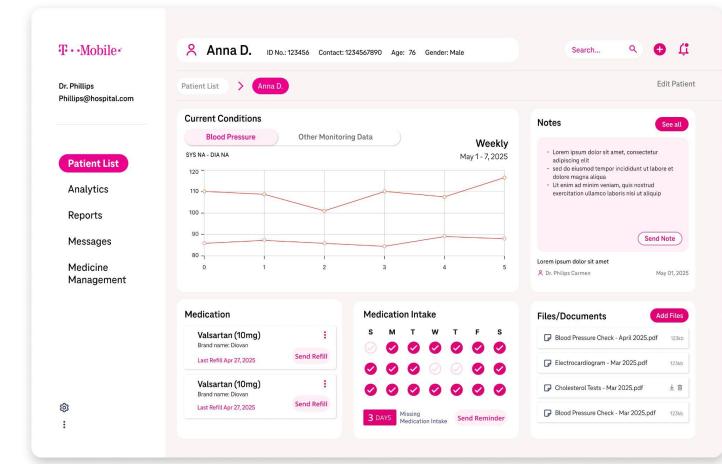
## 4. Notification from Caregiver

## 5. Suggestions

## 6. Medication refill buttons for notification

## 7. Notes from doctors

## 8. Patients' documents



# Patient Portal

The screenshot displays the T-Mobile Patient Portal homepage. On the left, a sidebar includes a search bar, a profile section for 'Hannah Xiao' (hx2213@u.wisc.edu), and a 'Log Out' button. The main content area features several cards:

- Medication Schedule:** Shows a circular progress bar indicating 'You have taken all pills today.' It lists medications: Blood Pressure (Once a day (10mg)), Daily Multi (Once a day (2 tablets)), Blood Pressure (Once a day (10mg)), Calcium (Once a day (1 tablet)), and Fish Oil (Once a day (1 tablet)).
- Blood Pressure Measurements:** A chart titled 'Medication Consistency: Okay' shows blood pressure levels over time. The Y-axis ranges from 80 to 140, and the X-axis shows dates from Feb 11 to Mar 17. Red dots represent Systolic pressure, and green dots represent Diastolic pressure.
- Suggestions from Doctors:** A card from Dr. Smith on May 3, 2025, suggests taking blood pressure medication in the morning with breakfast. Another card from Dr. Johnson on May 3, 2025, recommends reducing sodium intake to less than 2300mg daily. A third card from Dr. Johnson on Mar 1, 2025, provides exercise guidelines: aim for 30 minutes of moderate exercise 5 days per week to improve cardiovascular health.
- Prescription Details:** Buttons for 'Amount Changes' and 'Refill Notification'.
- Modality Preview:** A dark overlay shows a 'Pill Reminder' card with the message 'You haven't taken your medication today. Please stay on track.' and a 'Get It!' button.

## Framework & Routing:

- React application with React Router for navigation
- Uses Context API (UserContext) to manage user roles (like doctor or patient) and login state across the app without repetitive prop drilling
- Connects to Firebase for user authentication and dynamic health data retrieval

## Navigation & Layout:

- Fixed sidebar with T-Mobile branding
- Search functionality
- User profile section
- Settings and logout options

## Styling:

- Comprehensive CSS with T-Mobile Magenta color
- Modern UI elements (circular progress, cards, hover effects, trend charts)

# Doctor Portal

The screenshot displays the Doctor Portal's main dashboard for a patient named Hannah Xiao. At the top, there's a header with the patient's name, ID, contact information, age (23), gender (female), and a search bar. Below the header, the navigation menu includes links for Patient List, Analytics, Reports, Messages, and Medicine Management, along with a T-Mobile logo.

The main content area is divided into several sections:

- Current Conditions:** A tab for Blood Pressure is selected, showing a line graph of blood pressure measurements from February 9 to March 16. The graph tracks Systolic (red line) and Diastolic (teal line) pressures. A note indicates a missed pill this week.
- Blood Pressure Measurements:** A section showing medication consistency as "Okay".
- Medication:** A list of prescription items, including Valsartan (10mg) with a "Send Refill" button.
- Medication Intake:** A calendar for June 2025 showing daily medication intake. The 2nd of June is highlighted with a red circle, and a note at the bottom says "29 DAYS Missing Medication Intake" with a "Send Reminder" button.
- Notes:** A list of notes from Dr. Phillips Carmen, dated May 01, 2025, and Dr. Phillips Carmen, dated April 28, 2025. There's also a "Save Note" button.
- Files/Documents:** A list of PDF files: "Blood Pressure Check - April 2025.pdf", "Electrocardiogram - Mar 2025.pdf", "Cholesterol Tests - Mar 2025.pdf", and "Blood Pressure Check - Mar 2025.pdf". Each file has a size indicator (123kb).

## Architecture & Framework

- React-based SPA with functional components and hooks
- React Router for navigation between different portal sections
- Context API (UserContext) for user state management

## T-Mobile Styling Architecture

- CSS Grid for complex layouts (content areas, calendar)
- Flexbox for component alignment and spacing
- CSS transitions for smooth hover effects
- Design system follows T-Mobile's brand palette, using magenta highlights and light UI surfaces

# Reflections

## Hardware:

Incorrect voltage divider wiring issues on PCB, power bypassed photoresistors and directly went to resistors.

Solution: redesigning the schematic for proper voltage division between power and ground connecting to photoresistors and resistors, enabling successful operation with battery power.

## Software:

Integrated real-time data from two devices (pill detection & gesture camera) into one Firebase.

Solution: solved by using **Flask server** to integrate two data streams into a unified **Firebase database** for a user, enabling a complete medication adherence tracking system.

## Frontend UI:

Hard to coordinate a shared platform across teams due to three separate Firebase backends with large amount of data and difficult cross-navigation.

Solution: keep individual backends and route users based on credentials.



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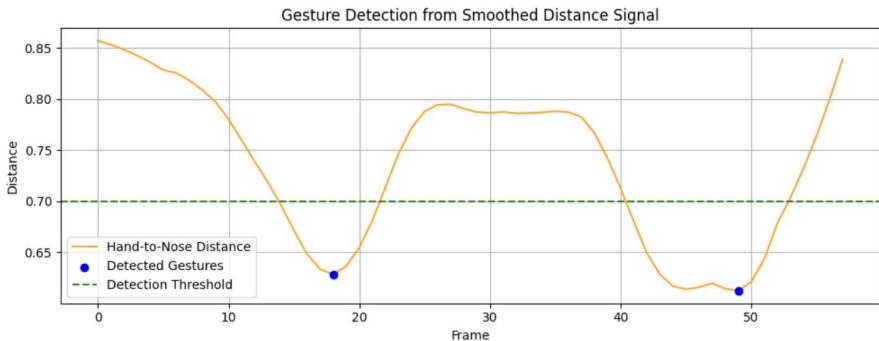
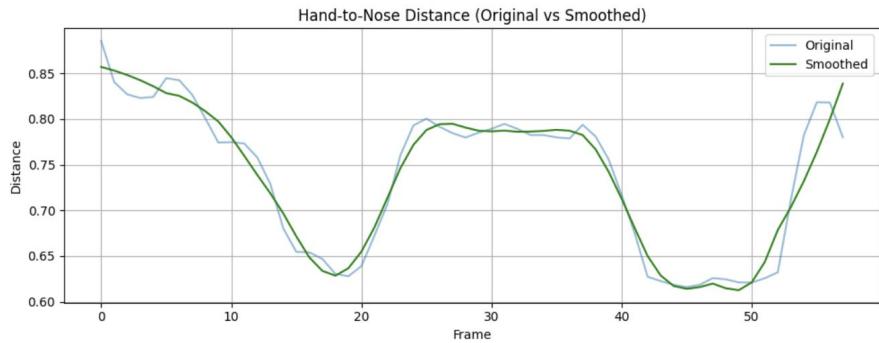
# Appendix: Gesture Tracking

The gesture detection works by tracking the distance between the hand and the nose (not mouth as it might be easily covered while eating the pill). These body parts are detected using MediaPipe, where the center of each part is tracked as a point.

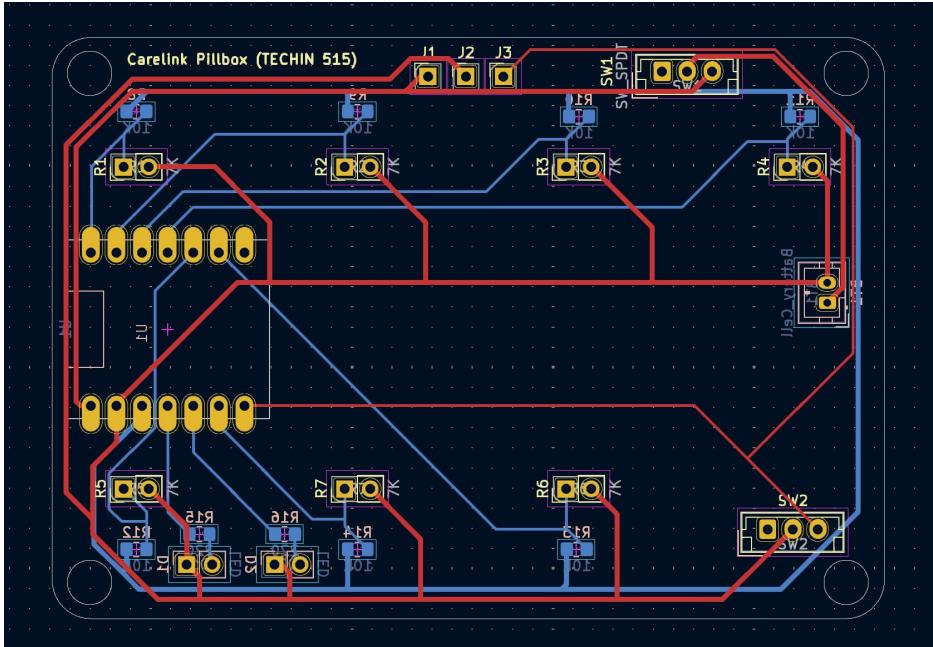
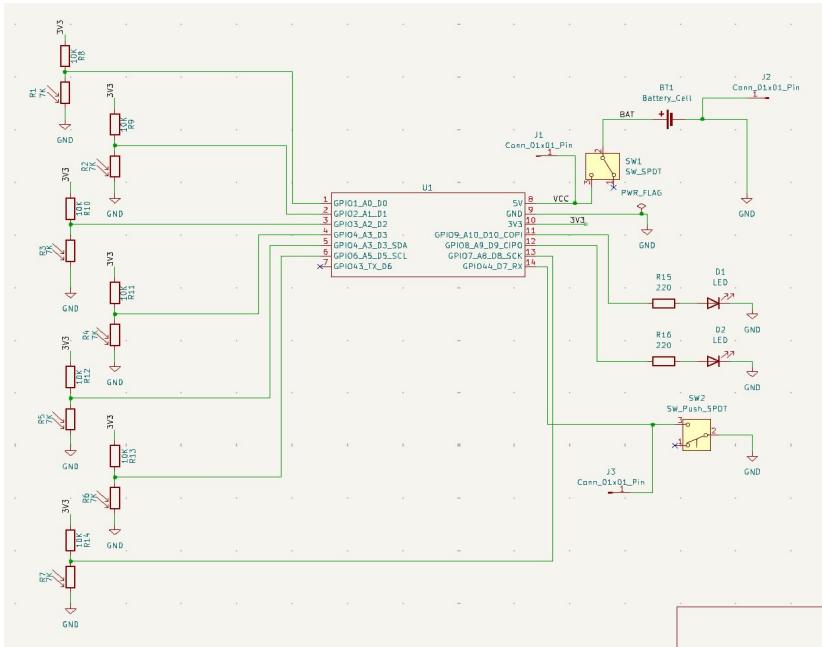
By tracking this Euclidean distance of these two points across the frames, we are able see the dips where the distance is the shortest.

DSP:

- **Savitzky-Golay low-pass filter:** reduces noise while preserving the overall gesture shape.
- **find\_peaks() from SciPy:** detects gestures by identifying the dips.
- **find\_peaks() constraints:** ‘distance = 10’ ignores dips less than 10 frames apart and ‘height = -0.7’ only detects peaks under 0.7.



# Appendix: Final PCB Design



# Budget

Month	Item	Notes	Link to the item	Unit Price	Quantity	Actual Expenses	Status	Note
April	Single Point Load Cell- 100g	Non-Amazon	<a href="https://www.phidias.com/p/100g-single-point-load-cell/">https://www.phidias.com/p/100g-single-point-load-cell/</a>	\$2.00	2	\$29.06	Arrived	Note
April	Seeed Xiao ESP32C3	Non-Amazon	<a href="https://www.digikit.com/p/seeed-xiao-esp32c3/">https://www.digikit.com/p/seeed-xiao-esp32c3/</a>	\$7.00	2	\$9.98	Arrived	Note
April	HiLetgo Photodiode	Amazon	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$5.78	1	\$7.06	Arrived	Note
April	NOVITO ADS1232	Amazon	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$14.99	1	\$16.27	Arrived	Note
April	HiLetgo ADS1256	Amazon	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$16.98	1	\$18.26	Arrived	Note
April	SparkFun Load Cell Amplifier	Returned	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$10.95	1	\$12.07	Not yet	Note
April	Xiao ESP32S3	Amazon	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$29.15	1	\$29.15	Arrived	Note
May	Xiao ESP32S3 Camera	Amazon	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$25.91	1	\$25.91	Arrived	Note
May	Lithium Ion Battery - 3.7V 200	Non-Amazon	<a href="https://www.adafit.com/p/37v-200mah-lithium-ion-battery/">https://www.adafit.com/p/37v-200mah-lithium-ion-battery/</a>	\$12.50	1	\$20.17	Arrived	Note
May	SUNLU 3D Printer Filament PL	Amazon	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$18.98	1	\$24.21	Arrived	Note
May	SUNLU PLA 3D Printer Filament	Amazon	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$18.98	1	\$21.68	Arrived	Note
May	Flexible Adhesive Mirror Sheet	Amazon	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$7.49	1	\$7.49	Arrived	Note
May	EEMB Lithium Polymer Battery	Amazon	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$12.66	2	\$27.90	Arrived	Note
May	Super Z Outlet Mini Round 2" I	Amazon	<a href="https://www.amazon.com/dp/B0B1VWZPQH">https://www.amazon.com/dp/B0B1VWZPQH</a>	\$11.75	1	\$12.95	Not yet	Note
								\$262.16

Remaining Budget: \$87.84 [350 - \$262.16]

[Link to up-to-date team budget](#)