UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

ECE 445: Virtual Reality Gloves

Electrical & Computer Engineering

Final Presentation for Senior Design at Illinois ECE

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Agenda

Motivation

Inspiration

Our Solution

Hardware Design

Software Design

Debug Diaries

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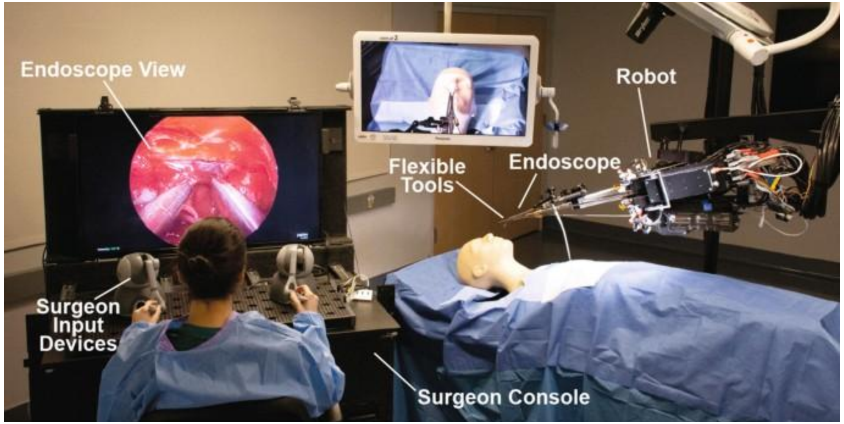
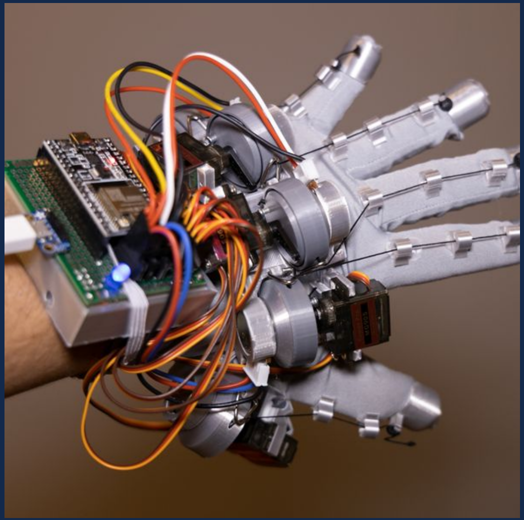
Motivation: Why do VR Gloves Matter?

- Hand/finger tracking is a **general HCI problem**.
- **Teleoperation:** surgeries, bomb disposal, deep-sea repair, space operations.
- **Accessibility tech:** neural intent decoding vs. finger tracking, ASL, etc.
- **Education/training:** for fine motor skills: medical, musical, lab equipment.
- Want it cheap and accessible.

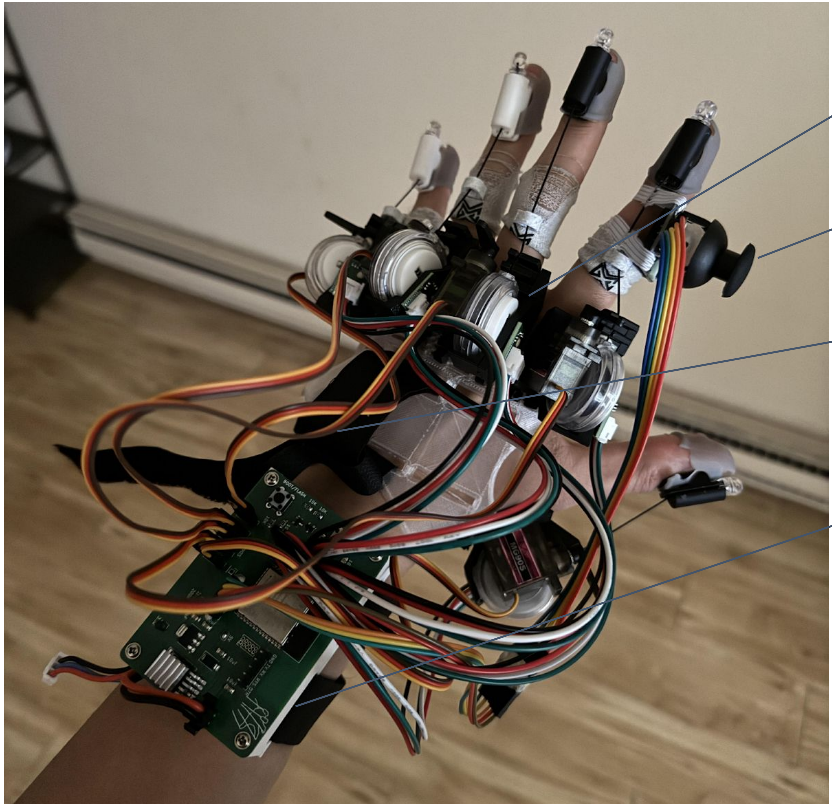




Inspiration: Lucid Gloves Open Source Project

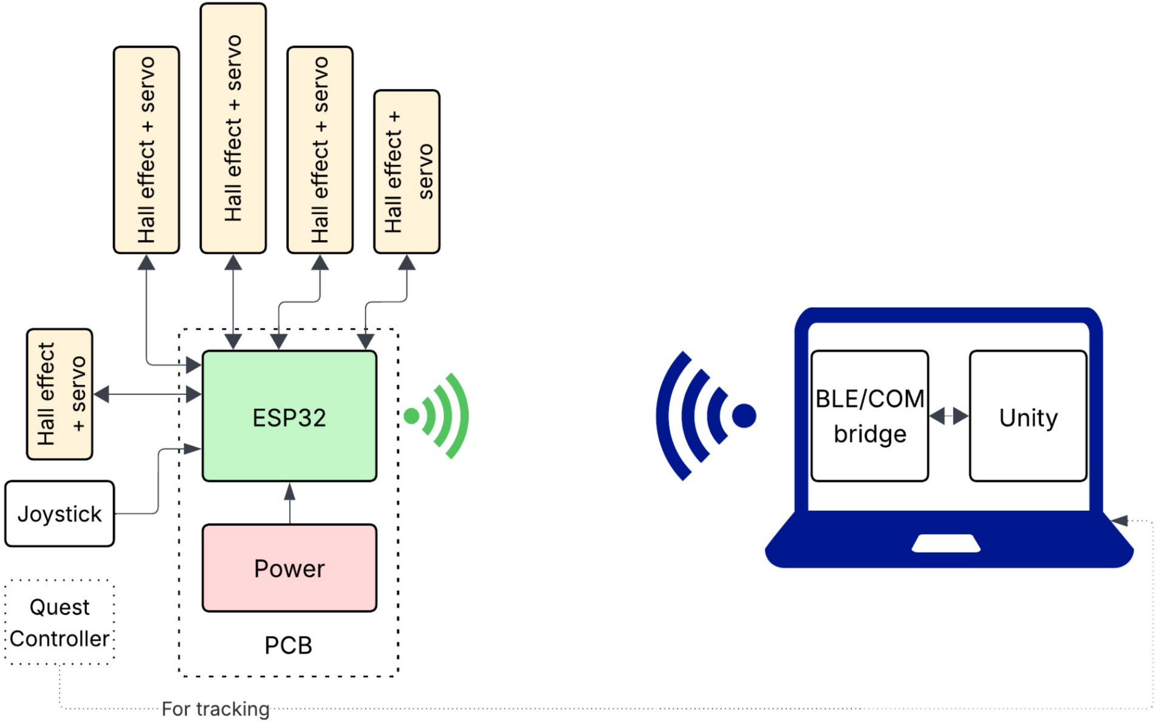
- V3: Potentiometers, badge reels (low res, range limited).
- V5: Hall effect sensors, 3D printed finger rails, haptics (high res, but needs precision 3D printing).
- Ashton worked on both V3 and V5!
- Idea: combine best of both versions.

Our Solution: Final Result



Final VR glove

Our Solution: Block Diagram



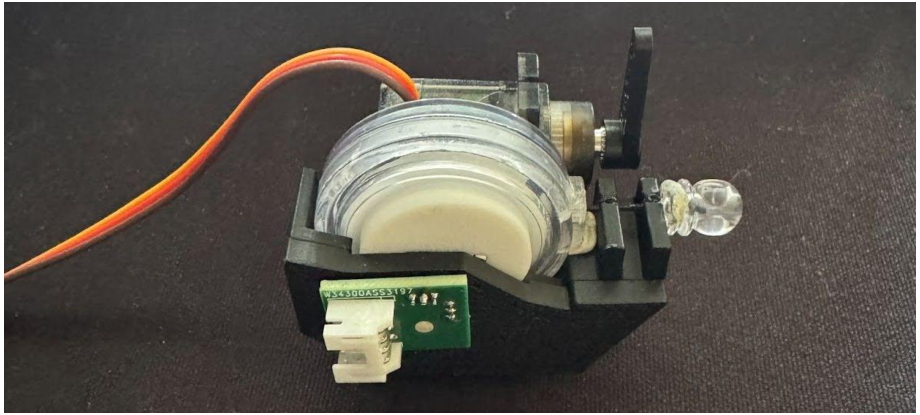
High-level block diagram of our design

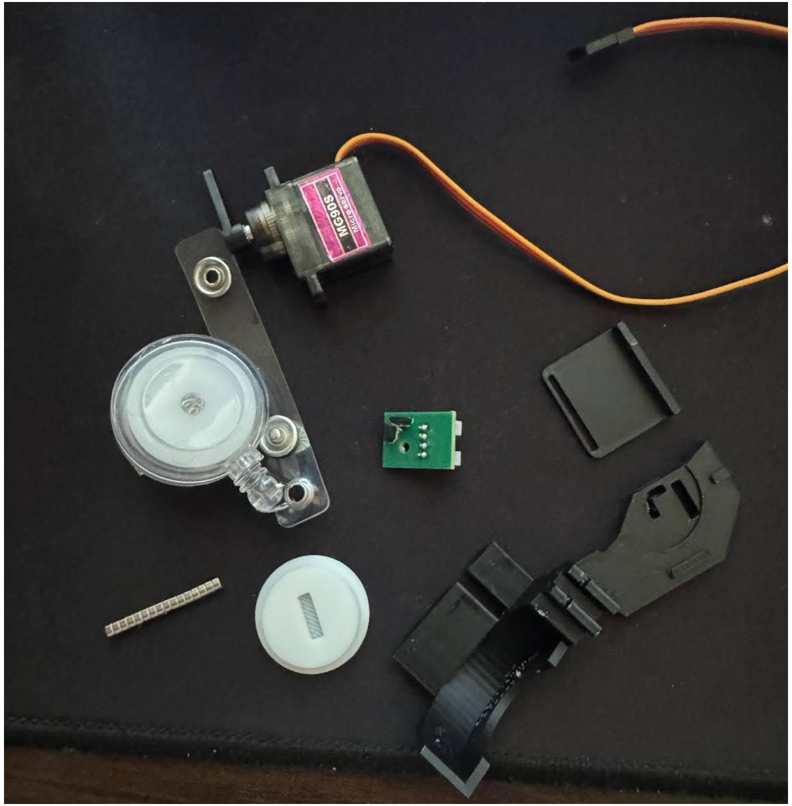
Hardware Design

Finger module, 3D parts, PCBs, Power

Hardware Design: Finger Module

- **Motivation:** minimize 3D printed parts (tolerance).
- **How it was built:** reused badge reel housing to hold hall sensors, servo motors.

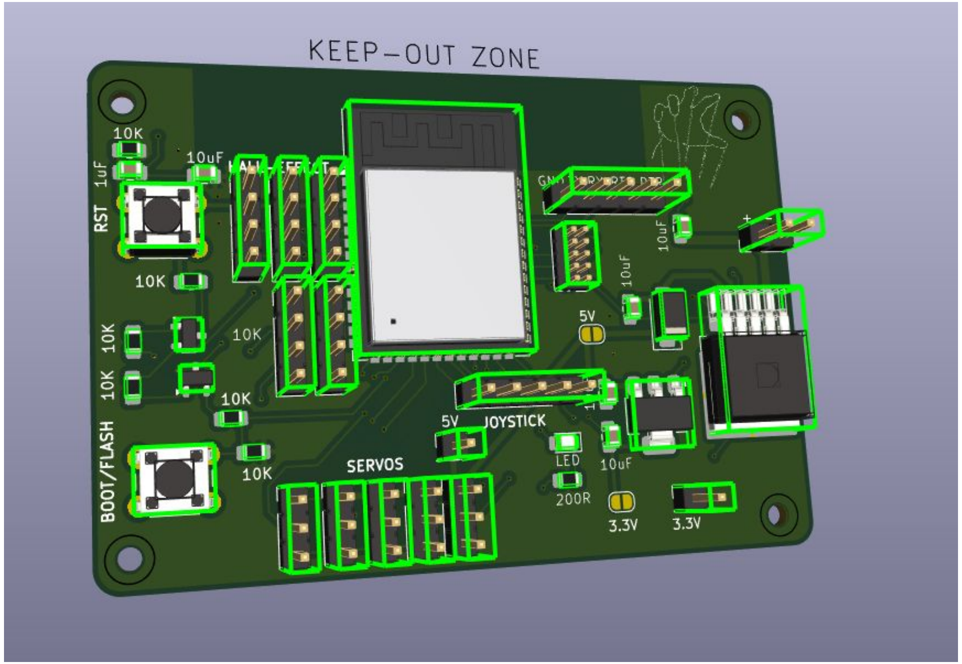


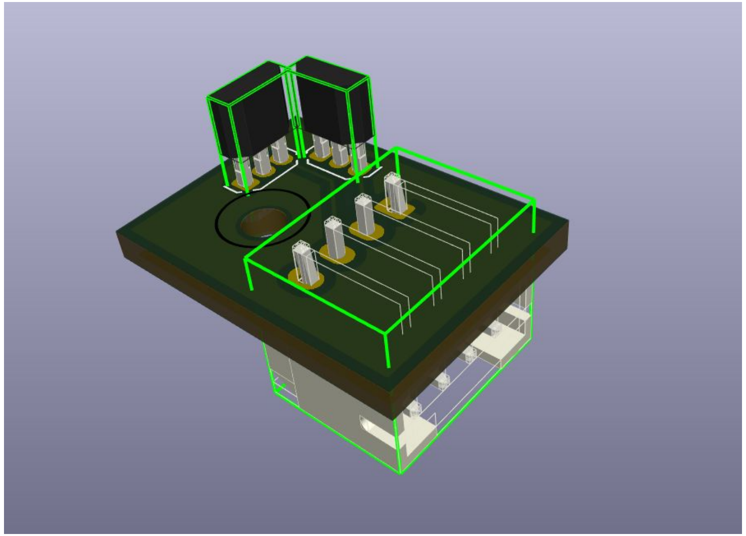


Hardware Design: Other 3D Parts

Hand mount, battery/board mount, finger attachments, glove

Hardware Design: PCBs



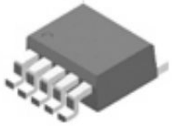


Main board (left), hall breakout board (right, 12.5mm x 17mm)

Hardware Design: Power

- **Battery:** 7.4V Li-ion Battery 2000mAh 2S Rechargeable.
- **Linear Regulators:** LM2596S-5.0 (7.4V to 5V), AMS1117-3.3 SOT-223 (5V to 3.3V).

Component	Quantity	Est. Current per Unit (mA)	Total Current (mA)
ESP32-S3 WROOM	1	~150 mA (WiFi active)	150
Hall Effect Sensors	10	~5 mA each	50
Servos (small hobby)	5	~300 mA each (peak)	1500
Joystick	1	~10 mA	10
Regulators + LEDs	-	~40 mA (combined overhead)	40
Total (average)	—	—	**1750 mA**



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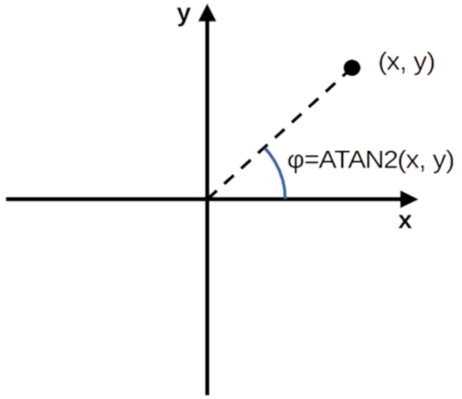
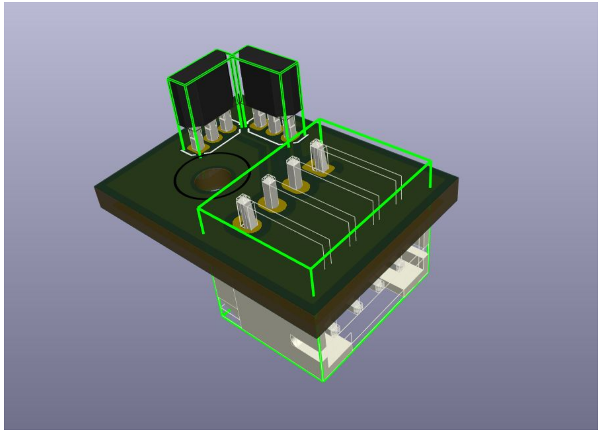
Software Design

Firmware, Bluetooth Bridge, Unity

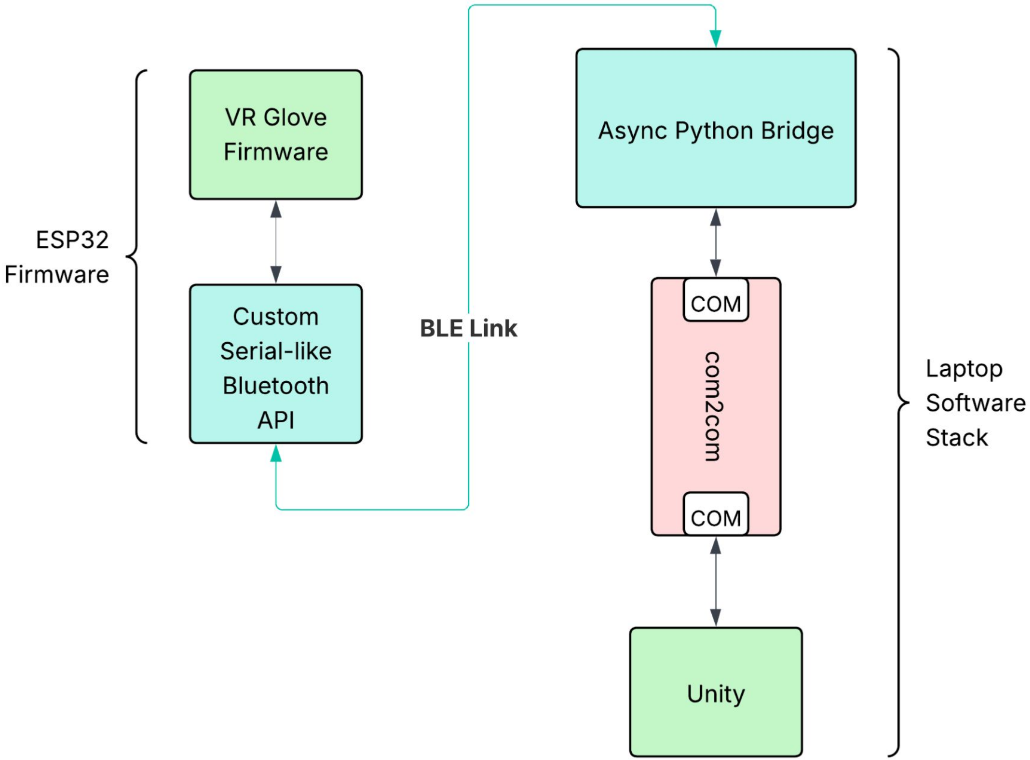
Software Design: Firmware



- Hall effect sensors are **perpendicular**.
- **Phase** of (x, y) voltage components provides finger measurement.
- Firmware handles **phase wrapping**.
- Sensor noise is **low-pass filtered**.
- Joystick buttons are **debounced**.
- Firmware serializes data for transmission.



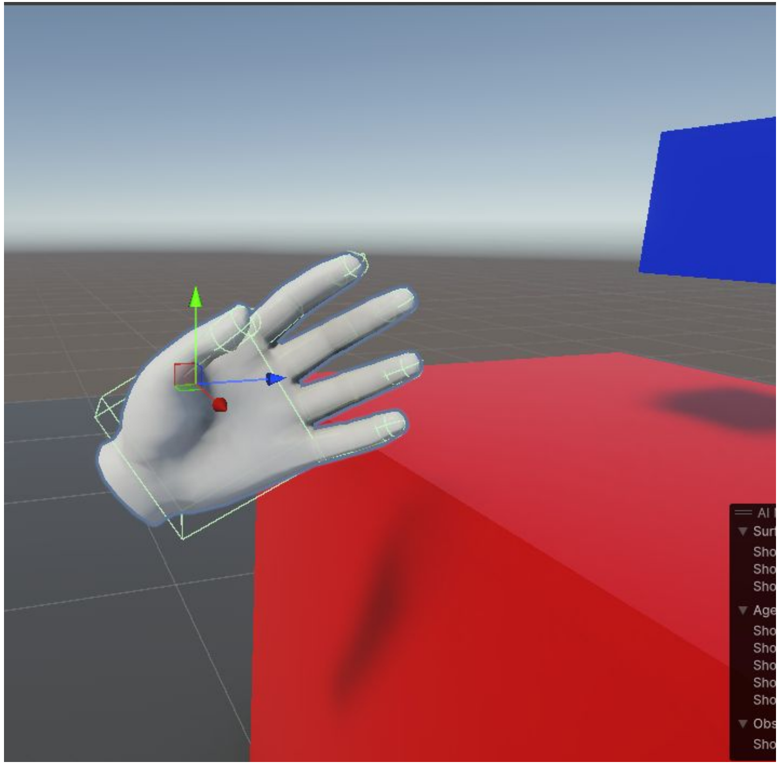
Software Design: Bluetooth Bridge



- **Goal:** drop-in BLE replacement for serial stack.
- Want to avoid rewriting Unity C# code for async BLE support.
- **Solution:** Shim ESP32 C++ firmware library, Python bridge.
- Unity thinks it's talking to serial.

Software Design: Unity

- **Unity + XR Interaction Toolkit:** Allows usage of Meta Quest and hand tracking.
- **Sensor data:** read serialized struct in via serial port, use data to animate virtual hands.
- **Virtual scene:** add colliders, rigid bodies for hands to interact with.
- **Servo data:** Colliders provide ability to send haptic data to glove via serial port.



Conclusion

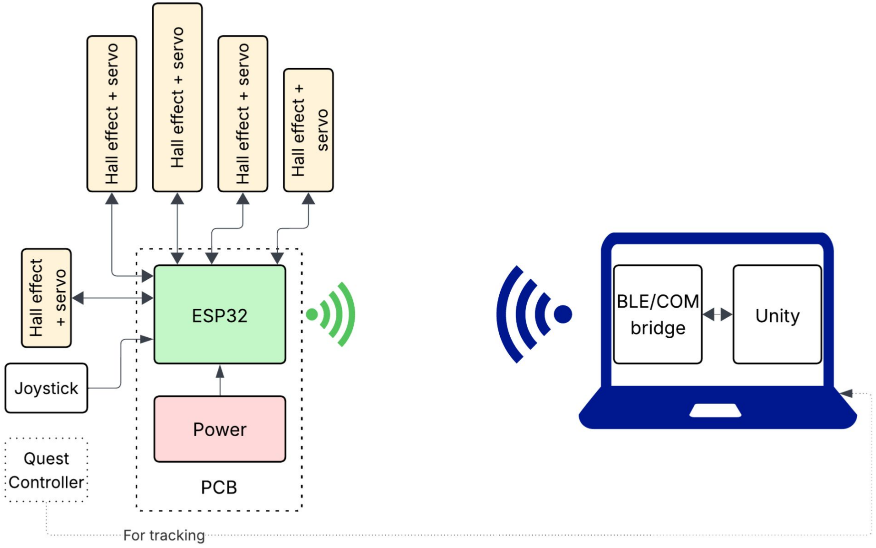
Debug Diaries, Accomplishments, Future Work

Conclusion: Debug Diaries

- **Reverse Polarity LED:** PCB soldering issue during bringup.
- **Hall-Effect Module:** Wrong KiCAD symbol for hall effect sensors.
- **USB-C PCB Debug:** Differential signalling (D+/D-) impedance and length matching issue.
- **3D Printer Tolerance:** Many many design iterations.
- **Animations:** How to animate hands? Use custom hands? Animations or key frames.

Conclusion: Accomplishments

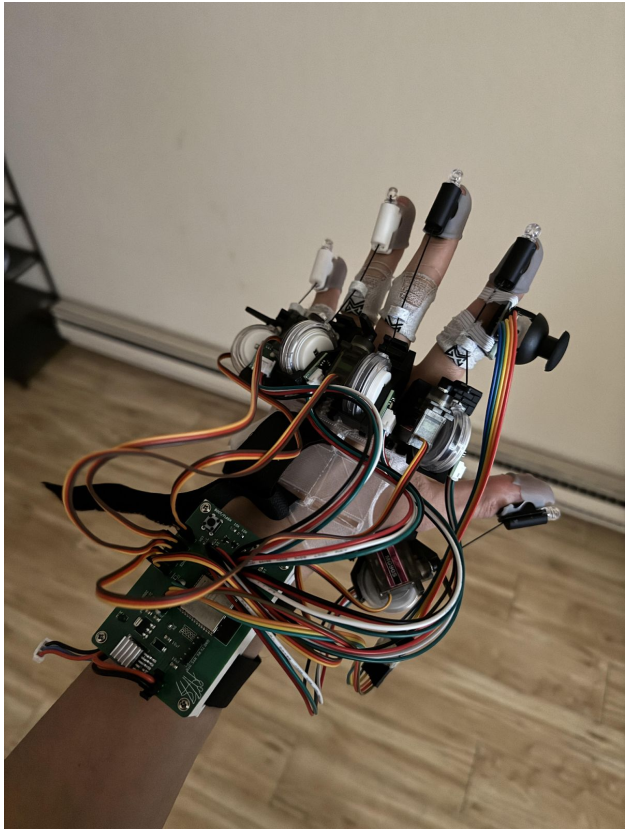
- **Low latency finger tracking.**
- **Low latency hand tracking.**
- VR headset deployable **virtual scene.**
- **Interactive virtual hands** within virtual scene**.**
- **Wireless (BLE)** capability**.**
- Allows for **haptic capability** with further dev work.



Conclusion: R&V Table

#	Requirement	Verification
1	Battery must regulate 7.4V LiPo down to 5V and 3.3V with minimal ripple (±5% tolerance).	Measure output voltages with oscilloscope under idle and load conditions (servos moving, sensors reading). Confirm 5.00V ± 0.25V and 3.30V ± 0.15V.
2	Dual Hall Effect sensors must produce independent voltage signals that correlate to finger flexion angles (±5° accuracy).	Move finger known angles using a protractor. Capture sensor outputs. Fit voltage vector to angle mapping. Confirm measured vs expected flexion within ±5°.
3	ESP32 must be successfully communicated with over a programming/debugging interface and respond to commands.	Program ESP32 to blink its onboard LED using a test script. Observe LED blinking to confirm that the ESP32 is powered, programmable, and responding to communication.
4	Servos must provide sufficient torque to lock the user's fingers in place, enabling realistic haptic feedback during interaction with virtual objects.	Apply external force to a locked finger and confirm that the servos can hold position against a small applied force, simulating physical contact in virtual environments.
5	ESP32 must maintain Bluetooth BLE connection and transmit flexion data.	Set up terminal and confirm reception of updated flexion data.
6	Multithreaded BLE-to-Virtual Serial Bridge must correctly translate BLE packets into COM port-readable data with latency less than 50 ms.	Send known pattern over BLE. Capture it on PC COM port. Measure time between send and receive. Confirm latency 50 ms.

Conclusion: Future Work



- Finish **haptics**.
- **Onboard position tracking** via IMU + sensor fusion.
- **Splay tracking**.
- Compatibility with **SteamVR**.
- Refine **firmware** (phase wrapping issue, angle resolution, calibration steps).
- Refine **hardware** (better PCB, battery choice, MCU choice).
- Refine **software** (complex test scene, fix movement, fix collider interactions).

Questions?

Thanks for listening!