DrumLite

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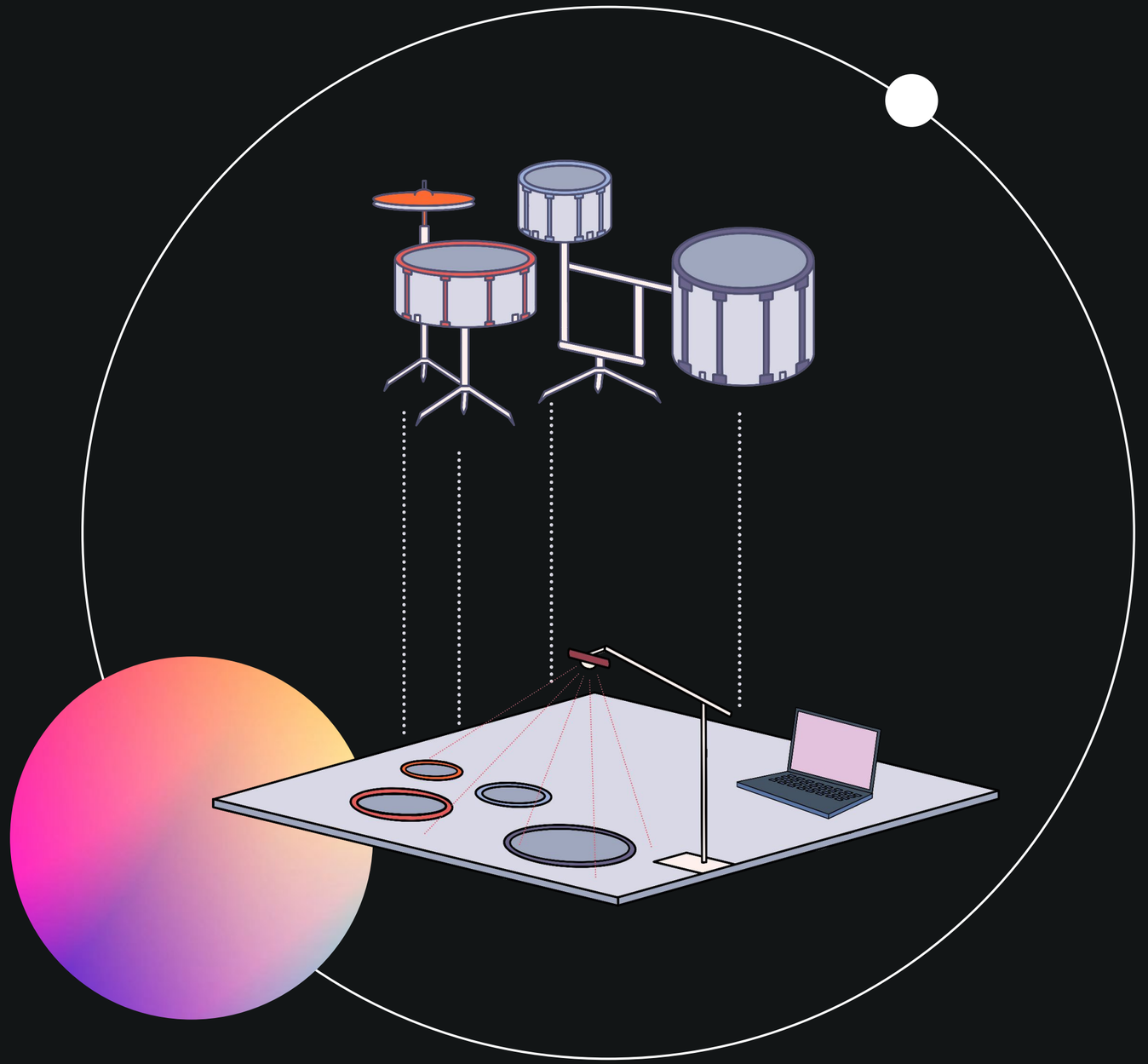
Team C0, ECE Fall ’24 Capstone



Solution:
Make playing the drums portable, versatile, and affordable.

PROBLEM:
Drum sets are heavy (~100 lbs), expensive ($600+), space-demanding (~20 ft^2), and take a long time to set up/disassemble.

APPLICATION:
Allow users to play an electronic drum set on any surface using machined drumsticks, a computer vision module, and a laptop. Build custom drum layouts in the DrumLite Webapp.

IMPLICATIONS:
Promote accessibility to those with financial, spacial, or audio constraints

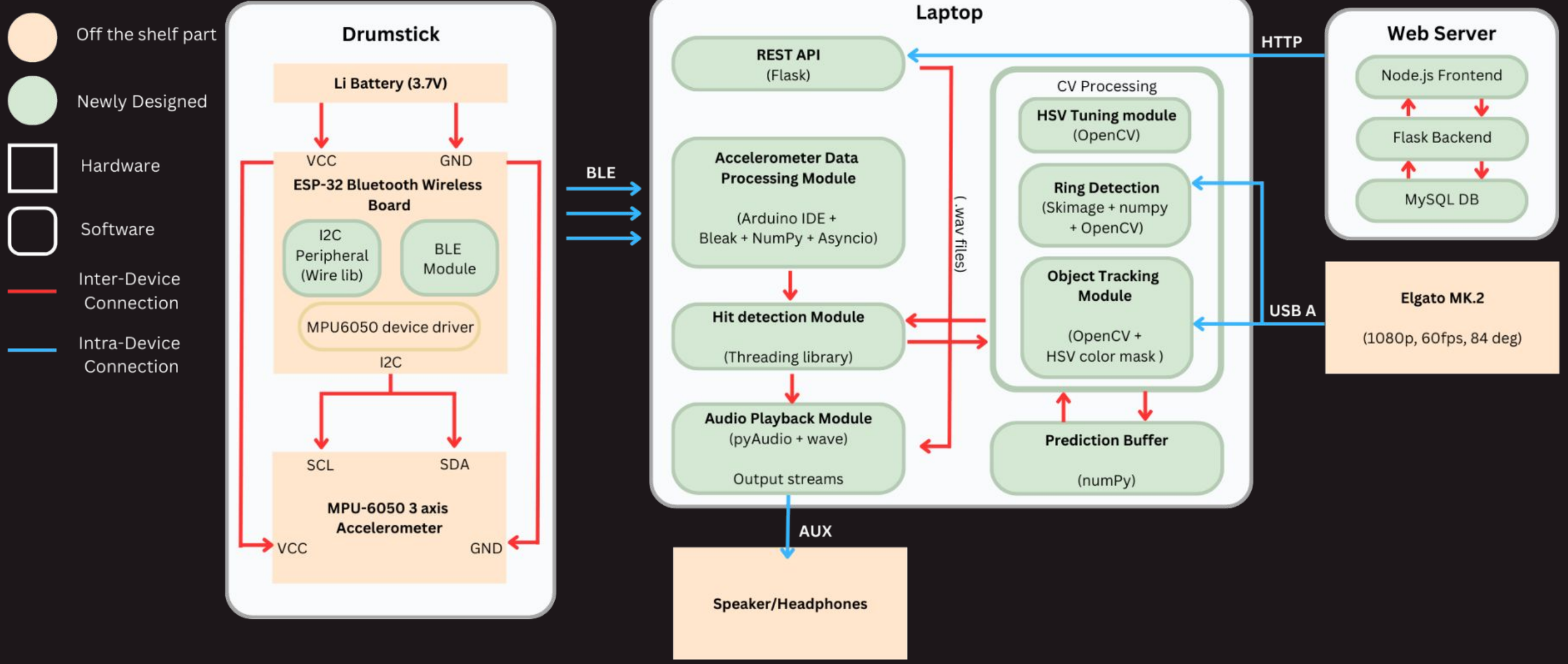
Use-Case & Design Requirements

Use Case Requirement	Design Requirement
Drum ring detection accuracy within ≤ 15mm of actual placement.	Scale detected circle radii by 15mm in pixels, depending on height of the camera
Audio response within ≤ 100ms of drumstick impact.	BLE response < 30ms, Accelerometer < 5ms, CV computation < 60ms
Achievable layout area of 1644cm^2.	Snare: 15.24cm Hi Hat: 17.78cm Tom: 20.32cm Floor Tom: 22.86cm

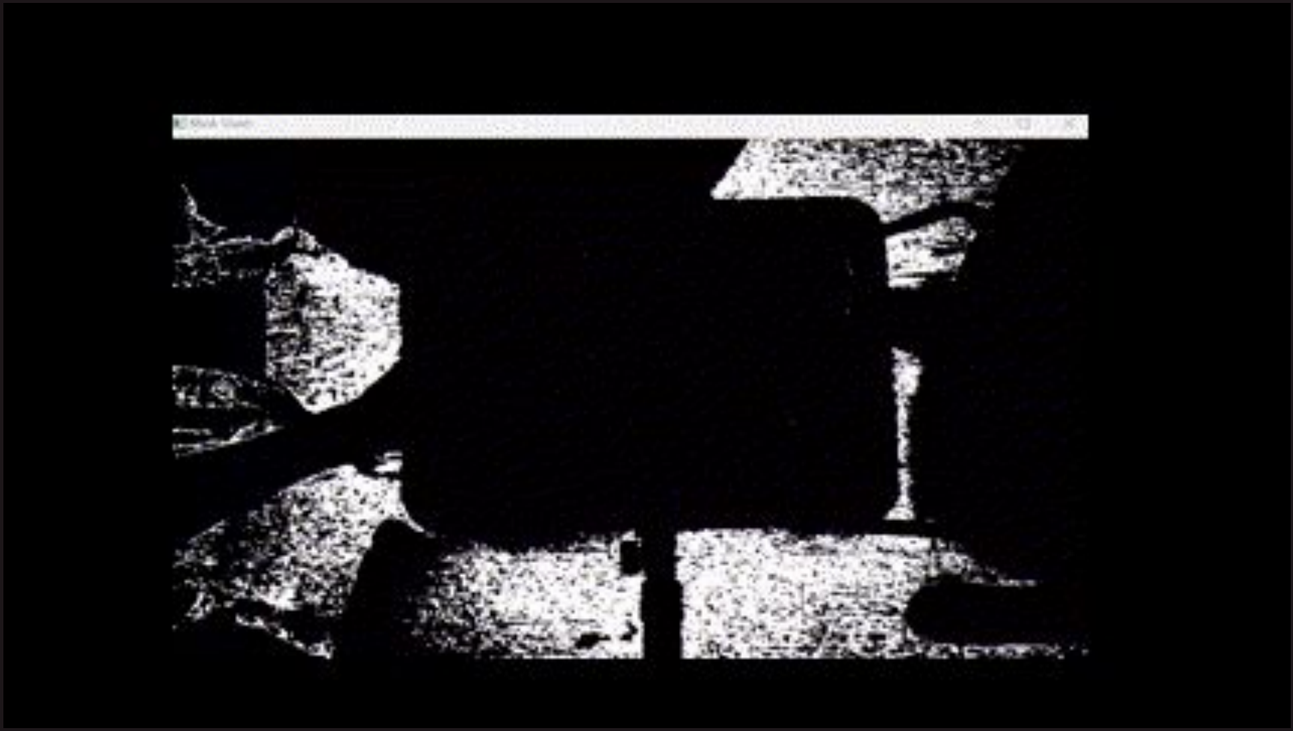
Use-Case & Design Requirements

Use Case Requirement	Design Requirement
Play sound for the correct drum ≥ 90% of the time.	Average stick location across all processed frames with $\alpha = 0.8$ for exponential weighting. $S_t = \alpha X_t + (1 - \alpha) S_{t-1}$
BLE transmission reliability within 10ft from laptop.	<2% BLE packet loss within 10ft radius of the laptop.
Machined drum sticks under 190.4g in weight.	Esp32 : 31g MPU-6050: 2g Drumstick: 113.4g Ensure connective components < 53.6g

Solution Approach



Complete Solution



-> Web application to configure audio files

-> Automated drum pad detection

-> HSV color picker

-> Concurrent drumstick actuation + audio playback

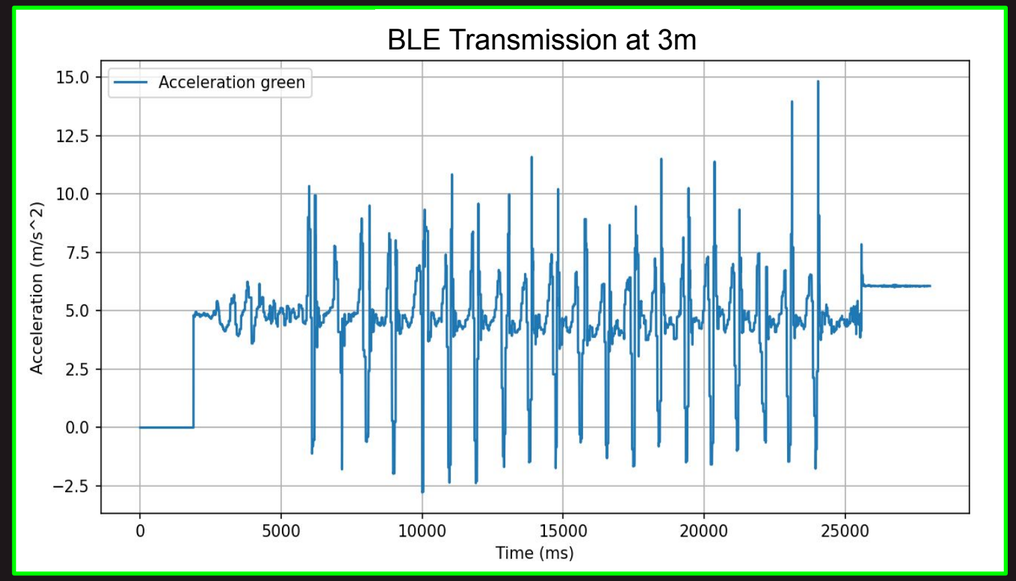
Validation

Use-Case Requirements

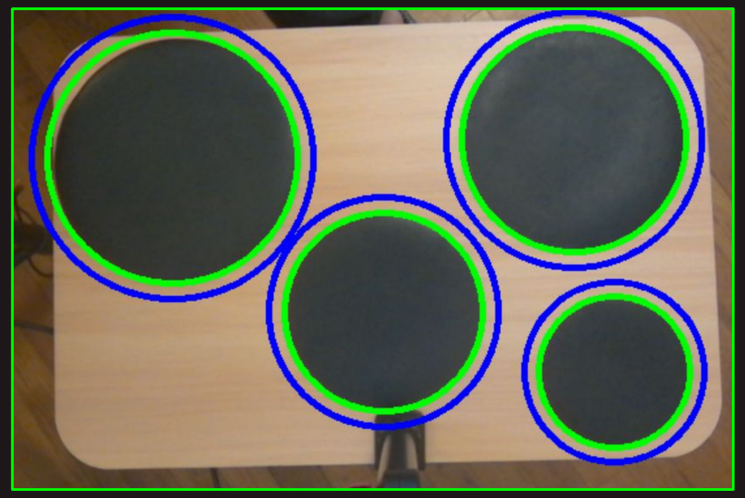
Requirement	***Test***
Drumstick weight < **190.4g**	Weigh each drumstick on a scale.
Minimum layout of **1644cm^2**	Organize drum pads and record relative measurements.
Drum ring detection ≤ **15mm** of actual placement	Run initial detection script Verify that an appropriate margin is added around the drum pads.
Reliable BLE connection within **3m** of laptop location	Setup drum pads 3m away from the laptop and graph received accelerometer data.
Play the correct drum's sound ≥ **90%** of the time	Play drum set alternating over each of the 4 drums and see if the expected sound is played.
Audio response within **100ms** of detected hit	Record a video(s) that shows when a drum is hit and when a sound is played. Measure the time between the two events.

Results - Validation

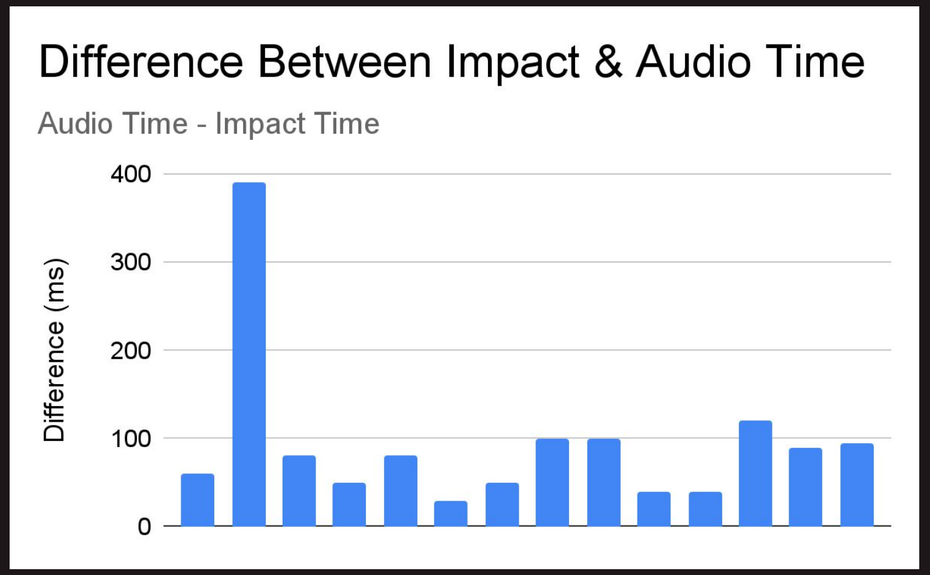
- Drumstick weight below 190.4g
  - ➥147g
- Reliable BLE connection within 3m



- Detect Drum Rings within 30mm of placement



- Overall System Latency below 100ms
  - ➥ average 94.1ms



- Correct drum sound ≥ 90% of the time
  - ➥ Of 100 trials, 89 reported correct drum -> 89%

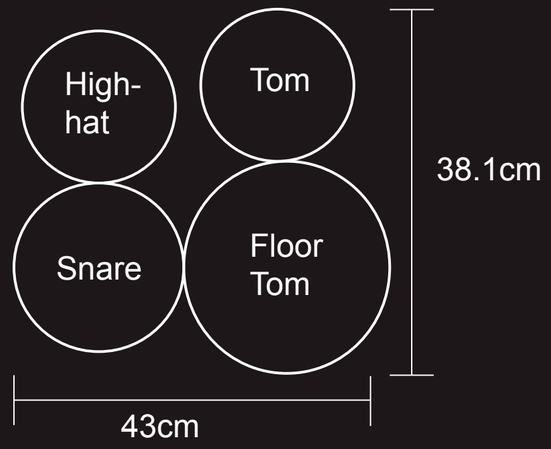
Verification

Design Requirements

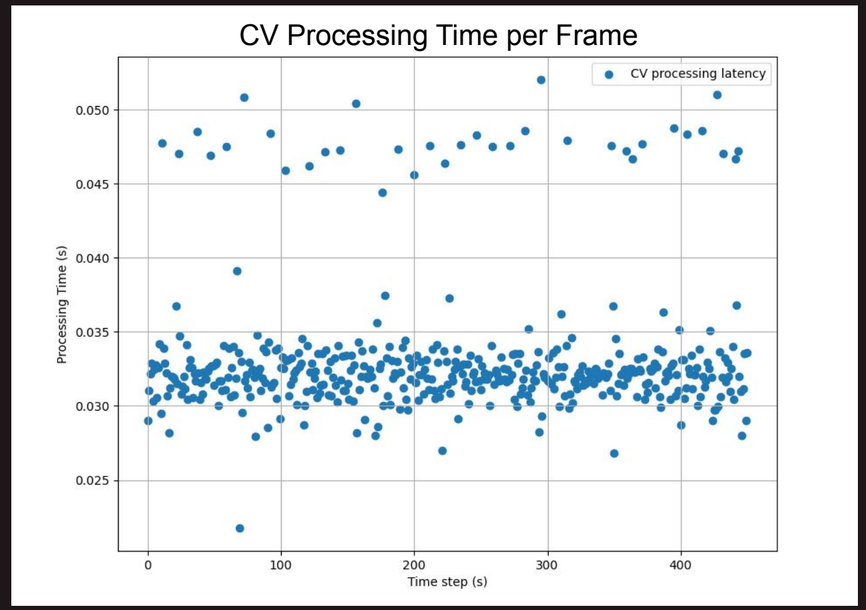
Requirement	Test
Connective component weight < **14.45g**	Weigh the 4 wires & tape on a scale.
Scale the drum pads down **50%**	Compare dimensions to full-size standards.
Dynamically scale the radii of the drum pads to add the equivalent of a **15mm** margin	N/A
Ensure < **2%** packet loss for BLE transmission	Track packet counters on MCUs and Host
Apply exponential weighting across all stored frames/predictions for a given impact	N/A
Ensure BLE transmission, CV, and accelerometer data processing latencies stay with **30ms**, **60ms**, and **5ms** respectively.	Record respective average values - RTT, CV processing per frame, and accelerometer + data processing latency.

Results - Verification

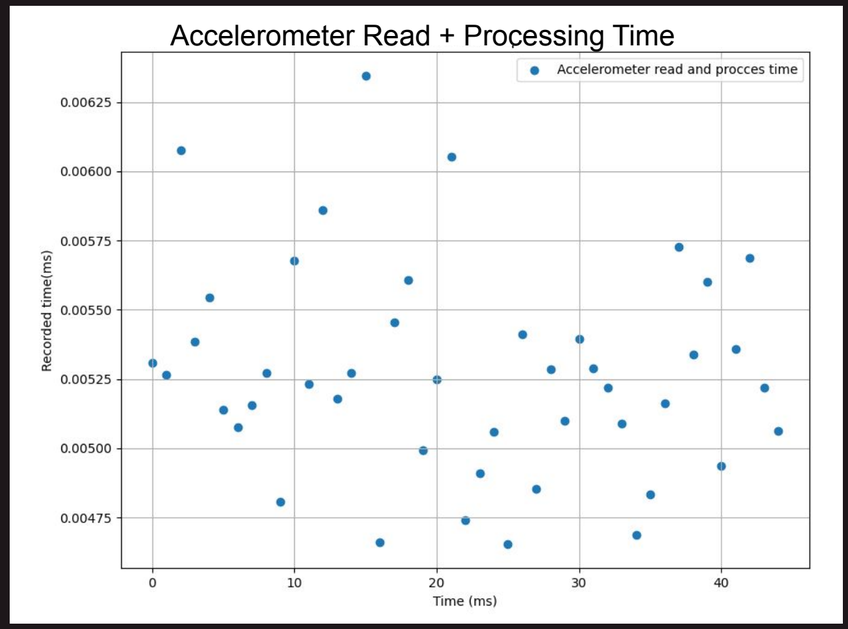
- Connective Components weigh < 14.45g
  - 5.1g
- Scale drum pads down by 50%



- Ensure packet loss < 2%
  - measured ~2%
- BLE RTT latency < 30ms
  - 17.3ms
- CV processing latency < 60ms
  - Average: 33.2ms



- Accelerometer + data processing latency < 5ms
  - Average: 5ms



Design Tradeoffs

Audio Streaming

- Buffered playback resulted in noticeable latency
- Writing audio frames to stream required no buffer
  queuing delay

Exponential Weighting

Prediction Buffer:

- Higher degree of prediction certainty
- Thread concurrency issues

Frame-Based Prediction:

- Slightly less certain location prediction
- Much fewer concurrency issues

Bluetooth vs. Wifi

Bluetooth:

- Convenience in connectivity
- Lower rate of interference
- Higher data rate for small packets

Wifi:

- Higher bandwidth
- Longer range
- Greater power consumption

Drum Pad Detection

Scikit Image:

- Slower execution
- Allows for specifying a number of circles to find

OpenCV:

- Rapid execution
- Finds *all* potentially circular objects in frame

Project Management