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BLISS: BLINKING LOW-POWER INFRARED SENSING SYSTEM

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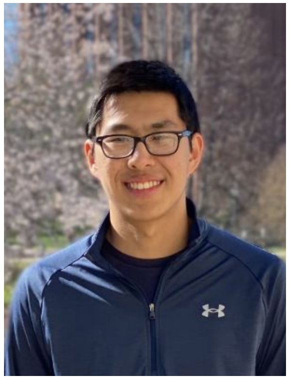

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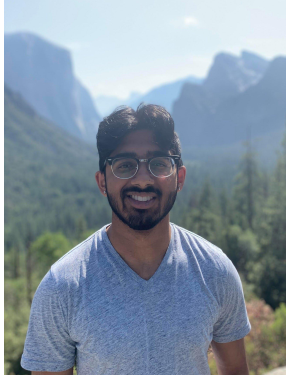

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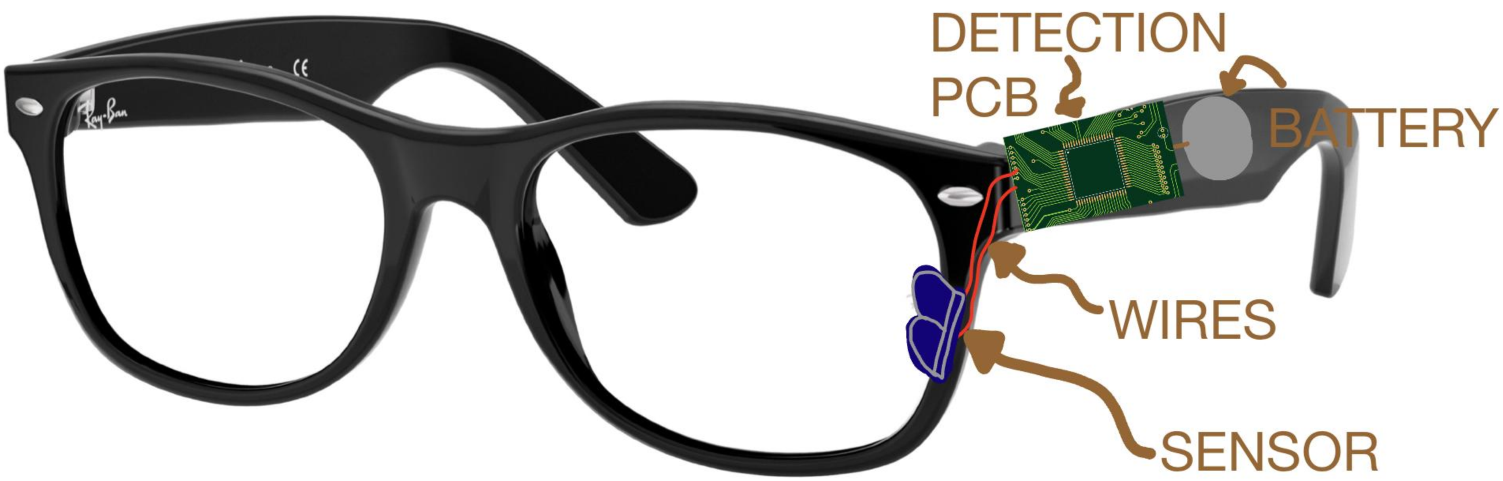
Problem Statement

- At least **1/3** of older adults suffer from insomnia
- **~ 60 Million** Americans suffer from chronic sleep deprivation
- Drowsy-driving deaths (~700 in 2020)
- **Increases** ocular symptoms and **problems** to the eye
- **81.9%** of engineering students suffer from Computer Vision Syndrome (CVS)

Project Goal

- BLISS will **detect** the user's eye blinks and **alert** them their behavior via vibrations
- We offer a low-power, minimal cost, and lightweight design to detect eye blinks



System Specifications

1. Detect blink frequency of the user to within **±1 blink/min**
2. Detect blink duration of the user to within **0.1 seconds**
3. Operate in a stable, indoors lighting environment
4. Be unobtrusive to the user when collecting data
5. Alert the user when their blink frequency is less than **12 times** per minute (average blink frequency is around **12 blinks** per minute)
6. Alert the user when their average blink duration is longer than **0.5 seconds** (average blink duration is around **0.5 seconds**)
7. Alert the user effectively yet discreetly
8. Observe eye safety regulations for IR sensor

Testing Plan

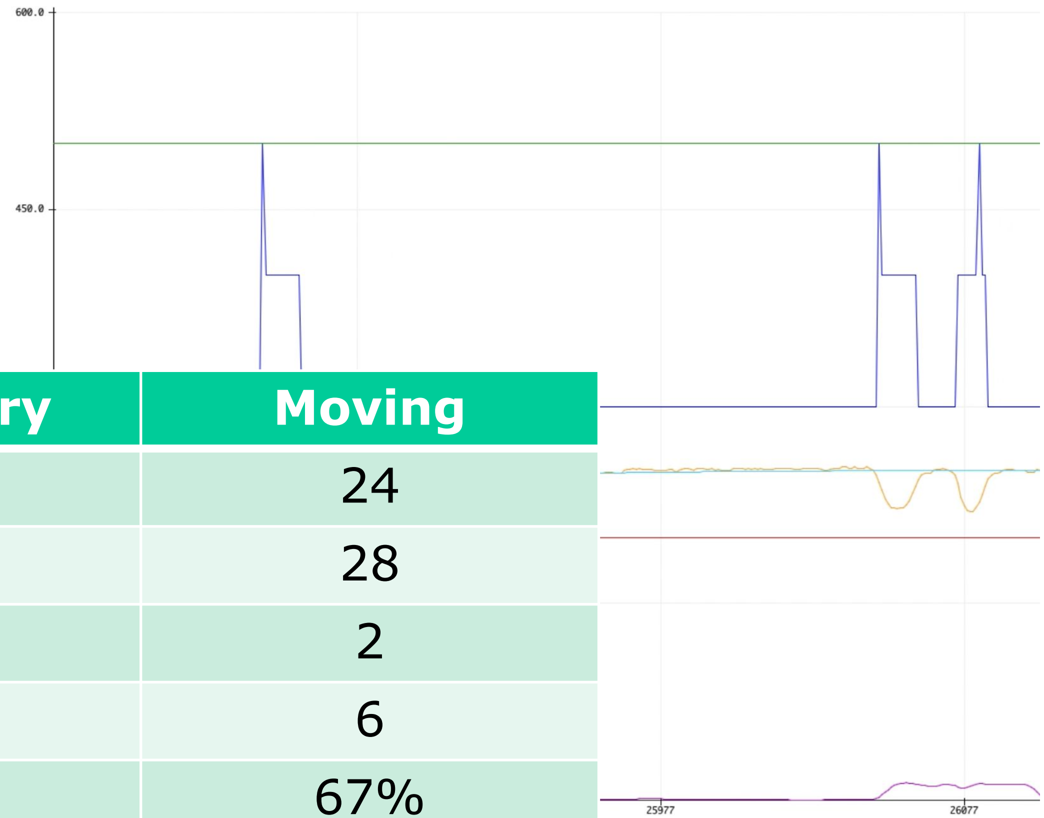
- Test the BLISS vibration feature when condition (CVS, fatigue, or falling asleep) is detected:
- Set up a test environment with a condition simulation tool or have a participant exercise to simulate condition.
- Ensure that the BLISS device is properly connected to the app on the demonstrator's smart device.
- Observe whether the BLISS device vibrates when condition is detected and record the results.

- Record tester's blinking behavior on video while wearing BLISS indoors, and manually count blinks and ensure accuracy over **90%**
- Check that average blink durations of over **0.5 seconds** get alerted
- Check that average blink frequencies of under **12/minute** get alerted

Test Results

Two 1-minute experiments:

Stationary head vs.
Constantly moving head

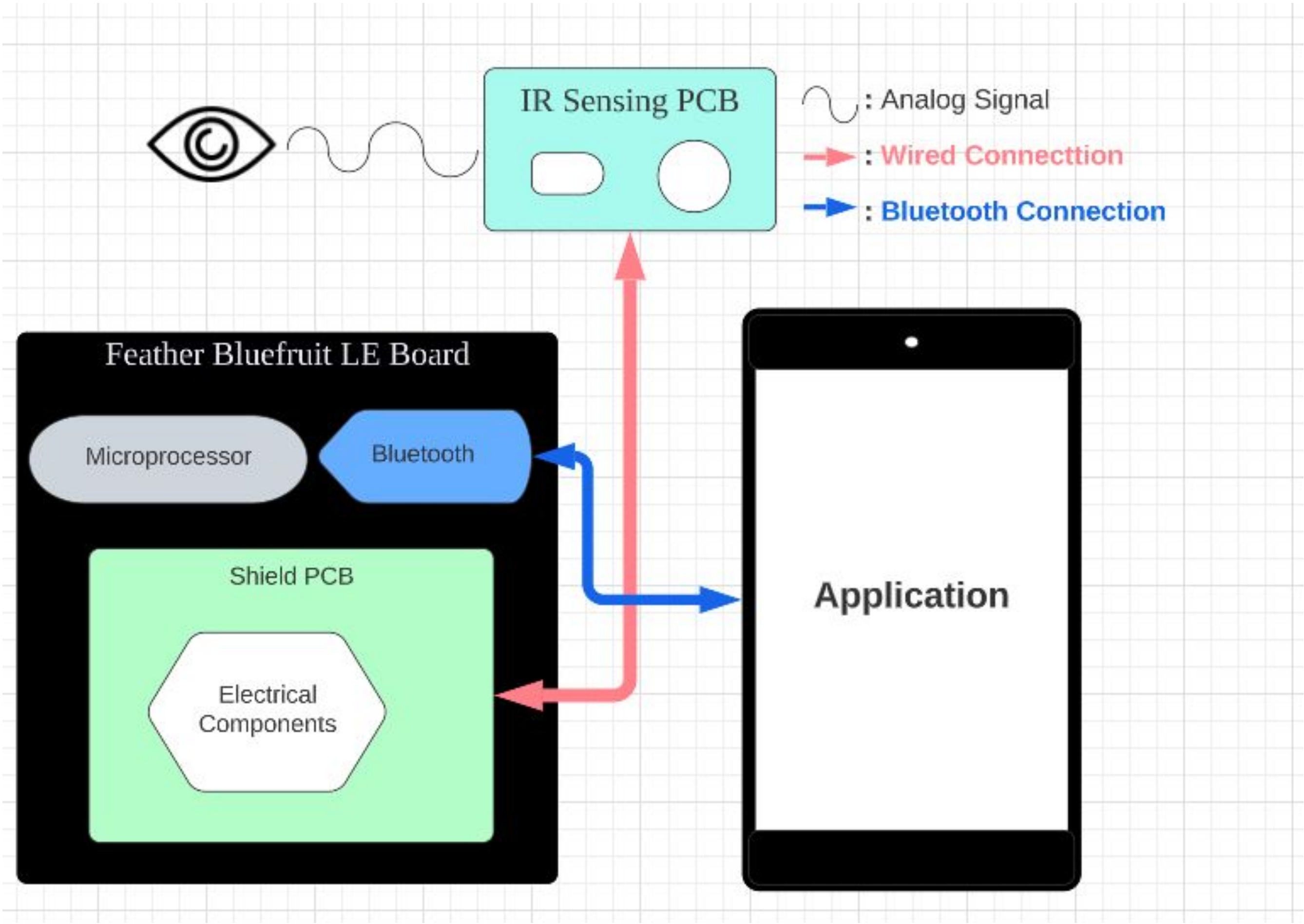


	Stationary	Moving
Actual blinks	34	24
Counted blinks	37	28
False negatives	0	2
False positives	3	6
Accuracy	91%	67%

Analysis of Test Results

- Stationary head yields much better accuracy as expected
- Head movements introduce unpredictable, erratic noise into the signal which cannot be filtered out
- Impact: use cases of the glasses are mainly in head-stationary cases, like using a computer or driving on a highway

Hardware Block Diagram



Hardware Justifications: 720nm emitter

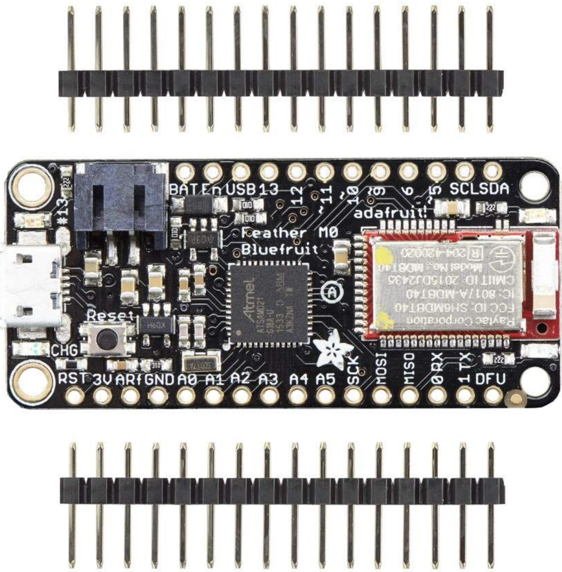
IR sensor

- Unit Price: $2.93
- Voltage Forward: 1.55V
- Current – DC Forward: 100mA
- Operating Temperature: -20°C ~ 80°C

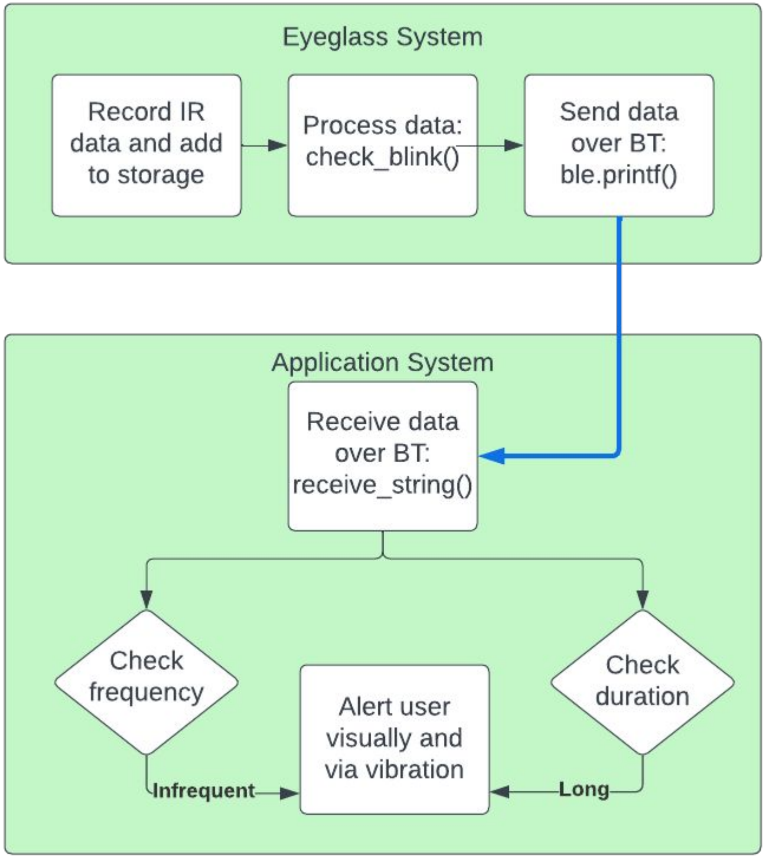
Hardware Justifications: Microcontroller Board

Adafruit Feather M0 Basic Proto - ATSAMD21 Cortex M0

- ATSAMD21 Cortex M0 based
- Bluetooth Low Energy (BLE) NRF51822 module
- Built-in USB and battery charging
- Cost: $29.95
- Current Draw: ~7mA
- Typical usage with peripherals running: 25 mA to 80 mA



Software Block Diagram



Algorithm Overview

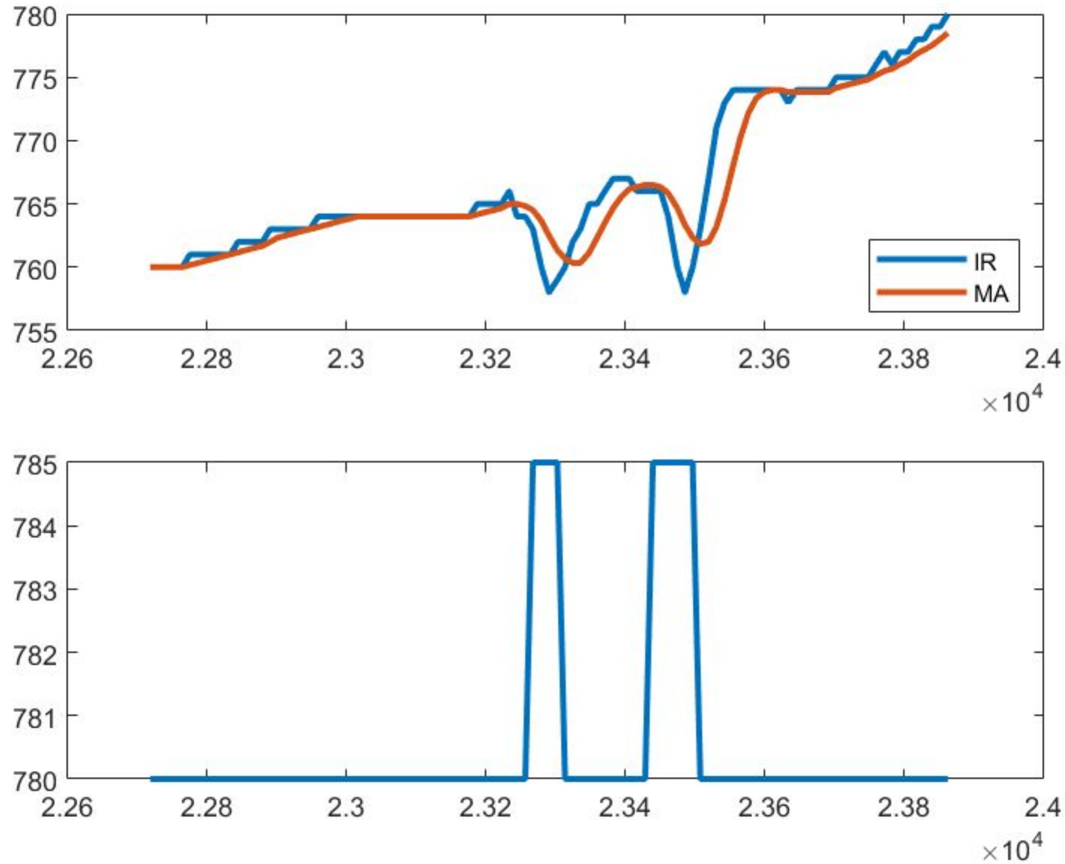
1. Sample IR sensor and smooth data
2. Calculate standard deviation
3. Calculate moving average weighted by standard deviation (higher STDs correlates with blinks)

- Blink edge detection: smoothed data slope exceeds threshold
- Blink duration detection: smoothed data is significantly different from STD-weighted moving average

Software: Sample Data Processing

Key features:

- Smoothed IR data
- Moving average
- Standard deviation threshold



Software Justification

- Computations done on-board the MCU
  - 75 samples can be collected and processed per second
  - Processed results (output to be displayed) sent once a second
- Custom blink detection algorithm
  - Unfilterable noise from irregular head movement
  - High standard deviation reveals blinks in data
  - Parameters can be adjusted to improve accuracy of the algorithm

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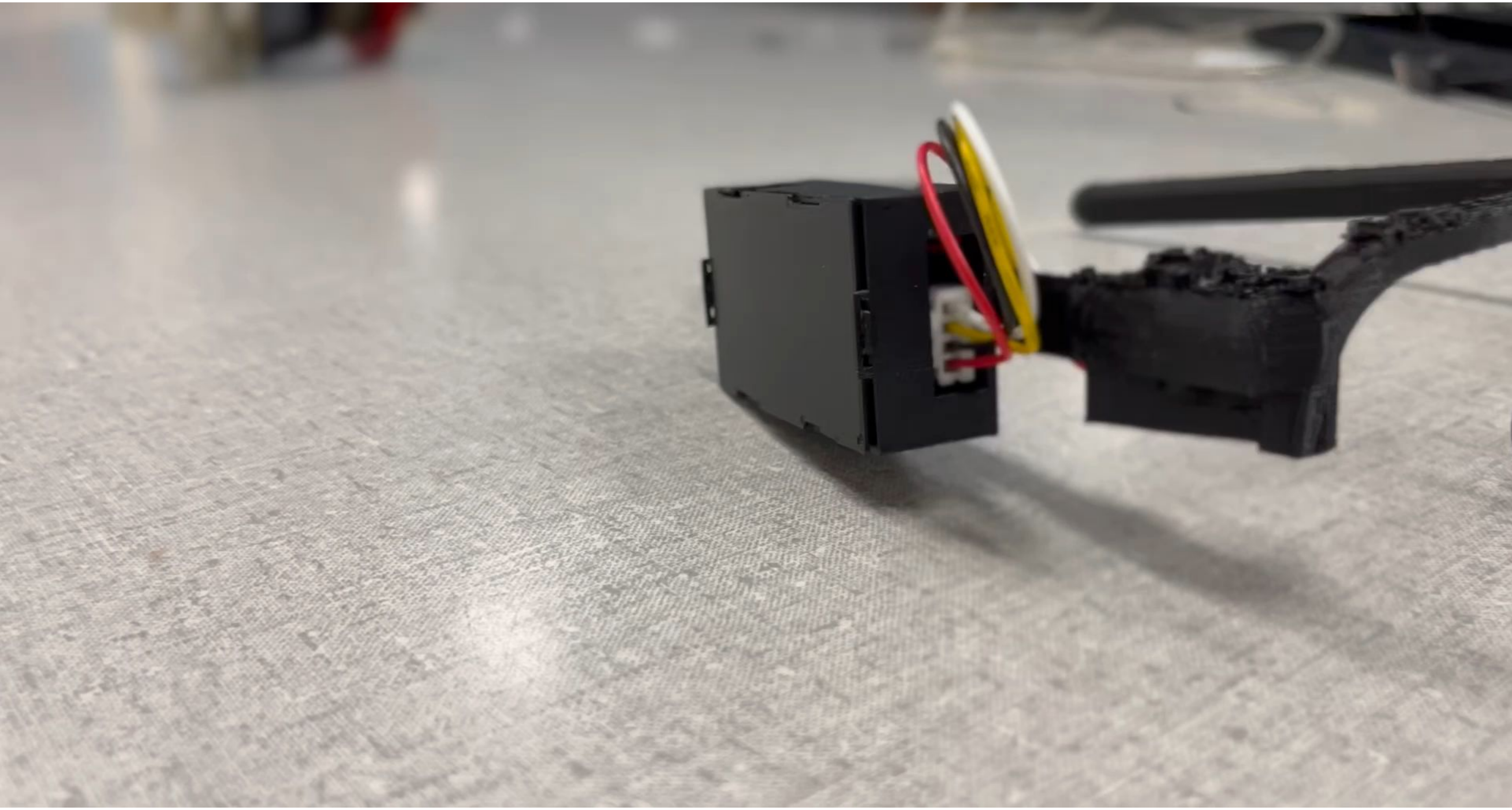
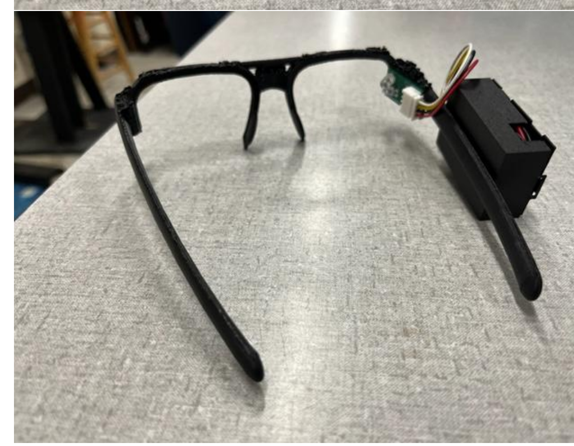
Final Product!



Live Demo!

CDR to FPR



FPR Deliverables

We will produce 1 prototype pair of glasses using a finalized PCB design

✔ The system will be contained in a 3D custom printed chassis

✔ The pair of glasses will communicate with a smart phone via BLE

✔ The system will detect blinks with >90% accuracy

✔ The user's blink rate and duration will be displayed on the smart phone display

✔ The smart phone should vibrate when long blink durations or low blink frequencies are detected

Key changes and improvements for FPR

✔ Improve aesthetics of the app
✘ Add reset functionality to the MCU
✔ Design improved PCB
✔ Design 3D printed part encasing
✔ Overall system should be lighter and smaller

Modifications to Deliverables

- Two-way Bluetooth connection was required for a reset button in the mobile application
  - Difficulty incorporating multiple data channels (BLE characteristics) hindered this effort
  - Work-around: the reset button onboard the Feather M0 can reset the counting of blinks

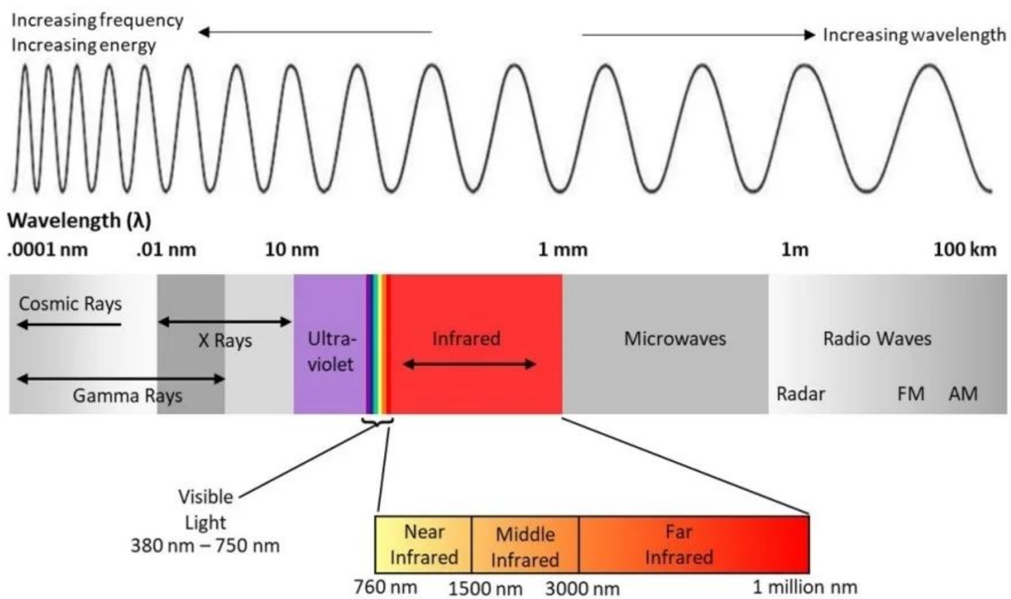
Addressing CDR comments and concerns

- Comment: "Strengthen the evaluation of the algorithm."
- Action: We added a second experiment that compares the accuracy of the system under different behaviors.

- Comment: "Power consumption with regard to overall power duty cycle."
- Action: The system has the IR sensors on constantly and the Bluetooth sends at regular 1-second intervals.

Safety

- We used 720 nm IR emitter.
- Radiation Safety Officer Haneef Sahabdeen from Environmental Health & Safety recommended below 780 nm IR.



Total Expenditures

Development

Period	Totals
PDR	$0.00
MDR	$58.35
CDR	$139.98
FPR	$222.81
Cumulative	**$421.14**

Final prototype

Part	Price
PCB	$5.13
IR sensors	$3.88
MCU	$29.99
Battery	$7.95
Total	**$46.95**

Final Balance: $78.86

Team Member Responsibilities

- Taisuke Miyamoto
  - Coding algorithms and application
- Tergel Molom-Ochir
  - Logistics Person
  - Circuits/Hardware Person
- Sashank Rao
  - Embedded Systems Programmer
  - Bluetooth
  - Financial Tracker
- Heta Shah
  - PCB Designer

Concluding thoughts

If we were to do it again...

- Things we would do differently
  - Minimize the cost of the product
  - Optimize components
  - Mobile app
- Things we would do the same
  - Overall design
  - Team cohesion

Thank you!

Questions?

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