SafeSight

Group 25

Matthew Carvajal
Computer Engineer

Albert Lougedo
Electrical Engineer

Mahyar Mahtabfar
Electrical Engineer

Project Motivation

Rush hour traffic - Miami, FL

Car Dependency in the U.S.

- About 92% of U.S. households have access to a car but only 55% of Americans have access to public transit. Additionally, only 3.5% of that 55% take advantage.

Roadway Construction vs. Vehicle and Population Growth

- SInce 1980, U.S. population has grown by 94 million or 41%, but highway capacity increased a mere 10.3%. With vehicle miles of travel more than doubling (102.3%)

Miami’s Crippling Infrastructure

- From 2021 to 2022, Miami’s traffic has seen an increase of 30%. The city now ranks as the 8th most congested city on the planet. The city’s failure to invest in public transportation, roadway development, and the population surge from post pandemic newcomers have all contributed to this current situation.

Distracted Driving Vs. Traffic/Safety

A steady rise in Digital Distraction

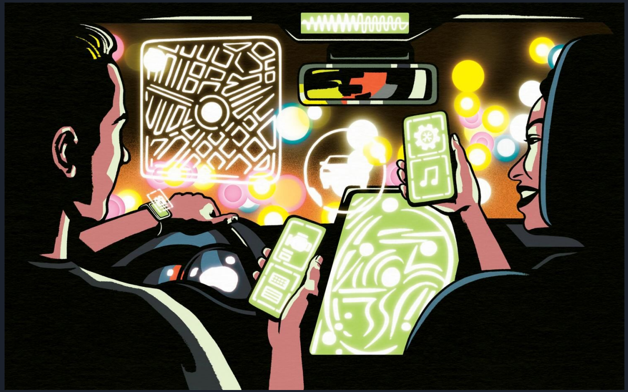
- On average, a person who owns a cellphone will check it around 96 times a day
- Addictive cell phone applications and improving technology in vehicles are to blame for an increase in distracted driving and elevated risks.

Safety Concerns

- Distracted driving leads to reduced safety and traffic flow.
- According to NHTSA, distracted driving claimed the lives of 3,275 in 2023 and claims that most distracted driving incidents are failed to be reported.

Proposition for the Problem at Hand

- A fully autonomous device that is compatible with any motor vehicle on the road and actively works to stop distracted driving, while collecting valuable driving data.



How technology has made your car a "candy store of distraction"

- *Los Angeles Times*

Introduction of Safe Sight

Safe Sight

- Create a product that collects data to expose attention infractions of drivers, while making real-time efforts to maintain driver attention on the road.

The Modern Horn Vs. Safe Sight

- Universally, a blaring horn is used as communication between vehicles and to alert other drivers of danger. Distracted drivers rely on other drivers to correct their attention on the roadway.
- Safe Sight will actively monitor the drivers posture in relation to their speed, acceleration, and reaction to changing traffic lights to catch and eliminate distracted behavior as soon as it starts.

Possible Markets and Applications

- Insurance, Company Vehicles, Long Distance Driving

Safe Sight Objectives

Benefits

- Ensure drivers remain attentive to the road at all times, including traffic stops
- Minimize distracted driving incidents, reducing the risk of accidents
- Improve overall traffic flow and roadway safety through proactive driver monitoring.

Capabilities

- Monitor driver posture to detect signs of distraction or drowsiness
- Measure acceleration and distance between vehicle ahead in relation to traffic lights in certain traffic stop scenarios
- Operate autonomously with no input from the driver, driver will be made aware of attention infractions from real-time notifications and alarms, and given a drivers report after driving
- Collect valuable driving data that can be displayed on a mobile application

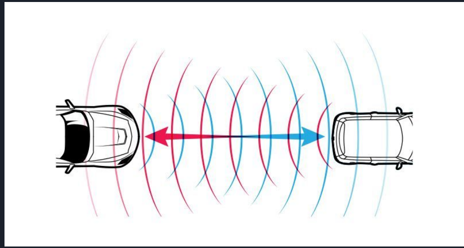
Safe Sight Technology

Computer Vision

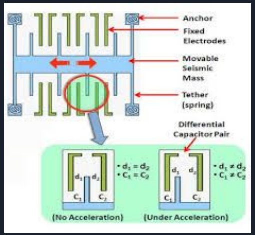
- Analyze traffic lights
- Gather information on the driver's head posture

Radar Distance and Accelerometer Motion Sensing

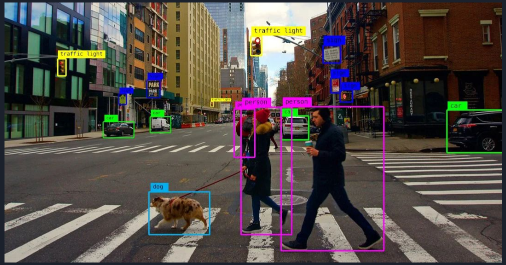
- MEMS Accelerometer technology to measure acceleration and speed relative to the vehicle
- Distance between vehicle ahead and drivers vehicle in traffic stop scenarios
- Once data on driver speed, acceleration, traffic scenery, and head posture is collected, we can start making real-time decisions on whether or not a driver is distracted in a multitude of scenarios



- mm Wave Radar Technology



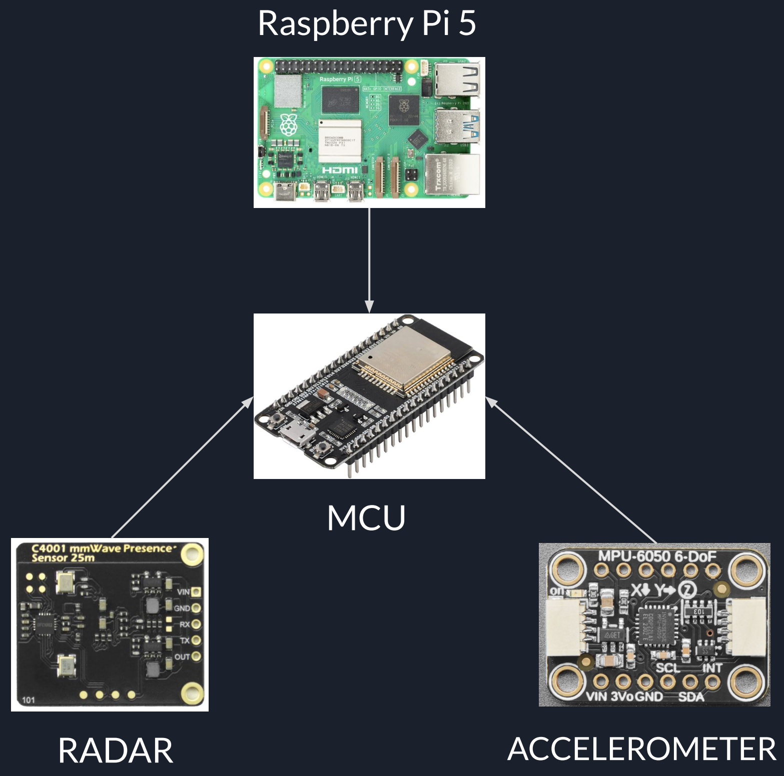
- MEMS Accelerometer Technology



- Computer Vision Technology

Major Component Selection Overview

- C4001 mmWave Presence Radar Sensor
  - Operates using millimeter wave radar technology to permeate driver windshield
- Raspberry Pi 5 8GB RAM
  - Serves as the Powerhouse to run the Computer Vision program and communicate to ESP 32 MCU
- ESP32
  - MCU that connects to all major and peripheral components that reads and writes information
- MPU-6050 Accelerometer
  - Provides Acceleration readings for MCU to dictate whether or not the vehicle is in motion
- USB Cameras
  - The “eyes” of safesight - collect real-time traffic and driver posture data to be analyzed by CV algorithms.

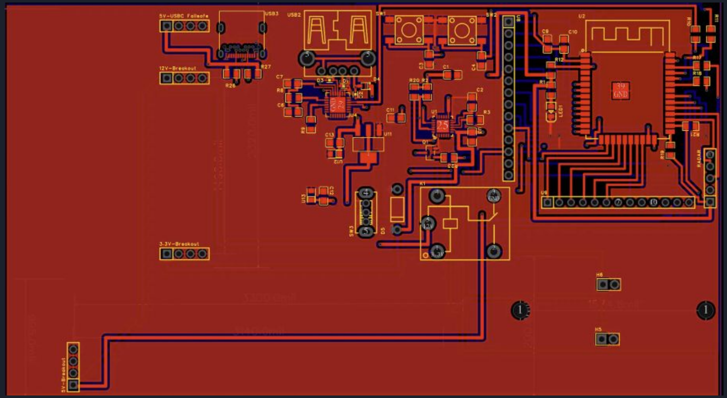


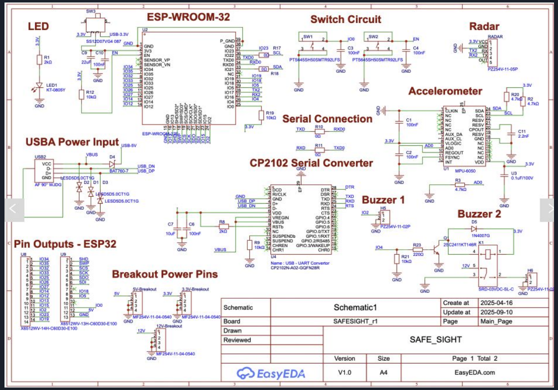
Hardware Comparison

	Other Considerations			Our Decision
MPU 6050 Accelerometer	<u>ADXL345</u> - 3 axes, no gyroscope, no magnetometer, no fusion algorithm. - $15 - More EMI Resistant	<u>BNO055</u> - 9 axes, Gyroscope, magnetometer, onboard fusion algorithm. - ~$30 - Higher accuracy, requires calibration.	<u>BMI160</u> - 6-axis IMU, I2C/SPI, low power, high performance	- Integrated 6-axis sensing - Onboard Digital Motion Processor - Cost Effective - Low power consumption - Wide SW support
C4001 mmWAVE Presence Radar Sensor	<u>Seed Studio mmWave Sensor</u> - 24GHz operation, motion detection, I2C/UART - Only 9-15 meters	<u>HIK-RD02/03D</u> - Human tracking, presence, and velocity detection - Can reach 12-16 meters - Not robust for noise, weather, traffic	<u>Other DFRobot Models</u> - Shorter range, less suitable for outdoor large-zone traffic sensing	- Long detection range with 25 meters - Wide beam angle, anti-interface, detection of static/ animate objects - FMCW modulation
ESP32	<u>Arduino UNO</u> - Single core 8-bit, 16MHz - 2KB SRAM - 32KB - No wifi/ bluetooth - 14-22 GPIO - 10 bit, 6-8 channels	<u>STM32</u> - single/ dual core 32/72 bit - 20-96 KB SRAM - **Some** wifi. Bluetooth models - 37-80 GPIO, 10 channels - Variable power options	<u>Raspberry Pi Pico</u> - Dual core 32-bit 133MHz - 264 KB SRAM - No wifi/ bluetooth - 26 GPIO, 3 ADC, 0 DAC - No built in sensors, low power consumption	- Dual core 32-bit 240MHz - 520 KB SRAM, 4-16MB flash - Wifi, bluetooth, 22-34 GPIO - 18 ADC channels, 2 DAC, - I2C,SPI,UART,(ultra-low power consumption)
Raspberry Pi 8GB	<u>Orange Pi 5 Pro</u> - 8 core, 2.4GHz CPU - 32GB LPDDR4 - Single camera support - Multiple USB port - High Cost	<u>Radxa Rock</u> - Quad/hex core, 4/8/16 GB options - Camera support - Multiple USB ports - Small community/ docs	<u>Nvidia Jetson Nano</u> - Quad-core ARM - 4GB DDR4 - NVidia maxwell 128-core - CSI, superior for vision - Cost is highest $$$	- Quad core 2.4GHz, 8GB RAM DDR4 - Multiple cameras supported - Largest SBC ecosystem - Moderate price for full functionality.

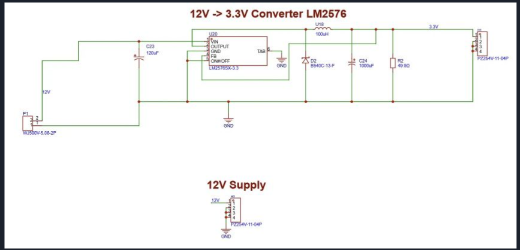
Main Board PCB

- Responsible for the communication and power delivery of all boards and components in this system.
- DC supply clines are thicker than the rest of the clines in order to reduce current density, minimize voltage drop, and increase power integrity.
- Power LED for visual check to ensure that the board is receiving ample power for each component.
- Expanded to fit the plug-in power regulator boards, radar, and raspberry pi.
- Ensured signal integrity for all traces with a copper pour on both the top and bottom layers.
  - This acts as a shield to the traces, confining electric fields and reducing emissions.

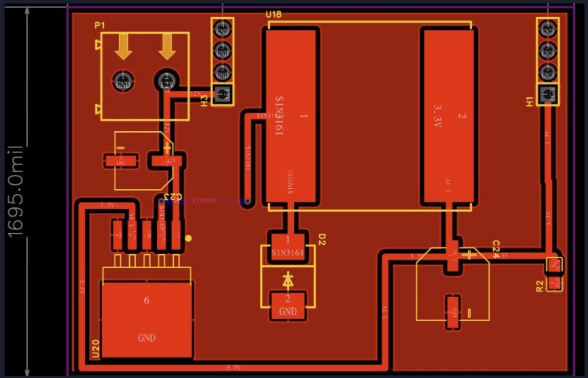


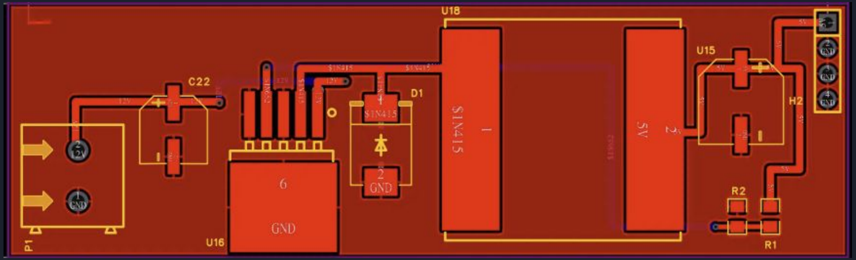


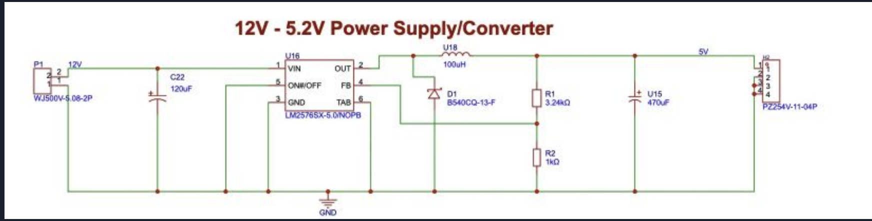
PCB Design



- Power Boards
  - We are providing input DC voltage at 12V from the car's cigarette lighter port.
  - In order to effectively power the subsequent technology on the main board we had to design both a 5V and 3.3V power regulator board.
  - Easier to debug and repair given the IC does not perform as expected
  - Pros:
    - Multiple pins for debug and repair
    - Multiple jumper-pin brakes for testing and energy flow.
    - Takes in 12VDC from the 12VDC car port and converts it to 5V and 3.3V (respectively).
  - Provides 88% efficiency from Ti's WEBENCH application.

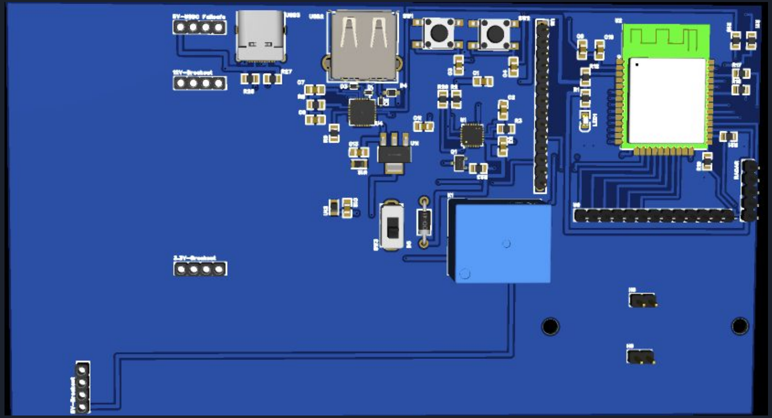


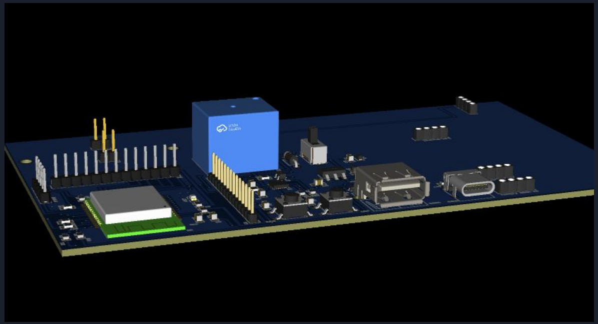




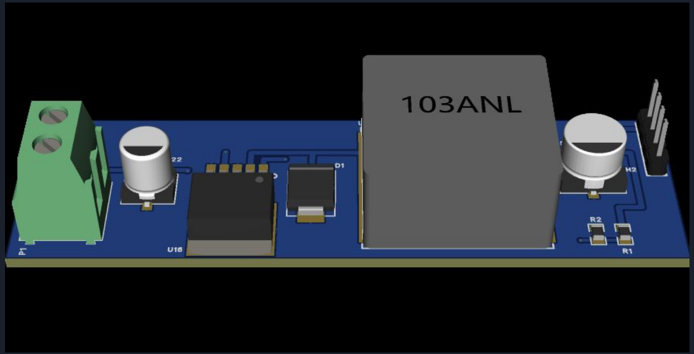
Hardware Progress

Main PCB

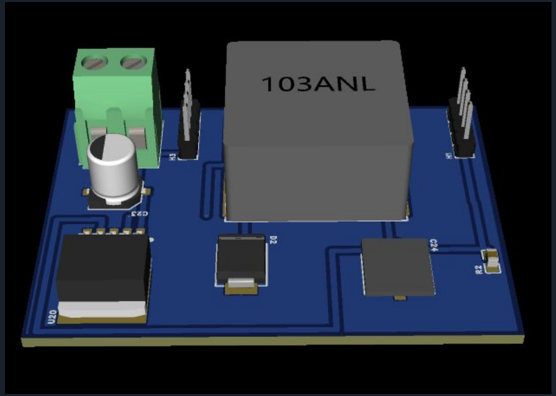




12V->5V PWB



12V-3.3V PWB



What’s Next for Hardware?

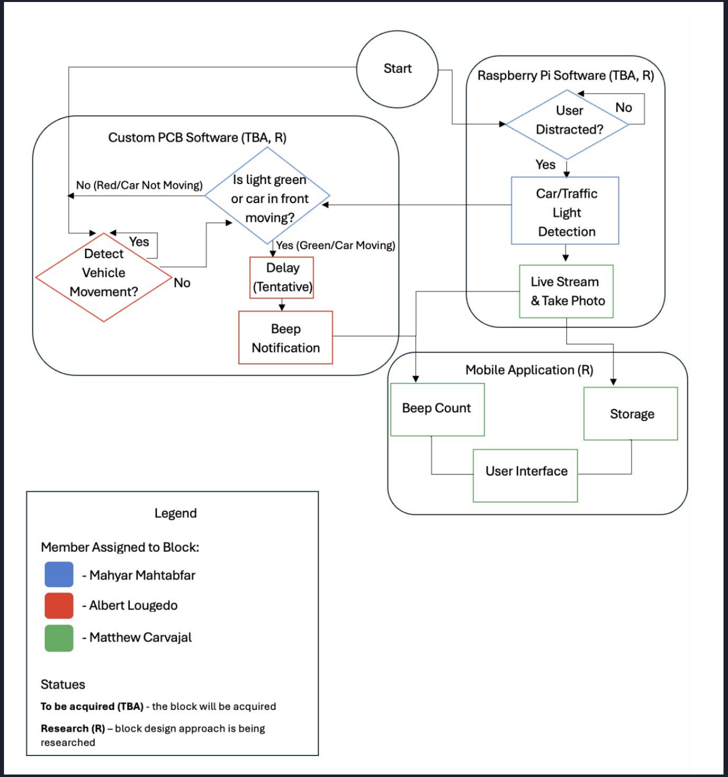
- PCB delivery alongside soldering and testing to ensure the system is functional with all components.
- Further integrate the software with the on-board hardware.
- Verify all power/ voltage regulators are working and effective.
  - Ensure transfer of data through copper tracings has little to no interference for proper data transfer between components.
  - Test Radar output data
  - Test Accelerometer output data
  - Test ESP32 bluetooth connectivity without interference
- Place the built hardware into dynamic traffic environment and record any errors
- Develop housing for the system to maintain board integrity and robustness in dynamic environments.

Software Selection

Technology	Pros	Cons
C/C++	- High performance and widely used in embedded systems	- Steep learning curve - Manual memory management - Error-prone and verbose
Swift/SwiftUI	- Modern and safe language - Great for iOS/macOS development - Fast and swift UI design	- Limited to Apple ecosystems - Small community and less resources available
Java	- Strong OOP support - Cross platform	- Verbose syntax - Slower than C/C++
Python	- Easy to learn - Massive library support	- Slower performance - Limited for low-level hardware interaction
Git/GitHub	- Popular with great collaboration tools	- Public by default - Can be difficult for beginners
Bitbucket	- Free private repos - Integration with Jira and Trello	- Smaller user community - Fewer integrations VS GitHub

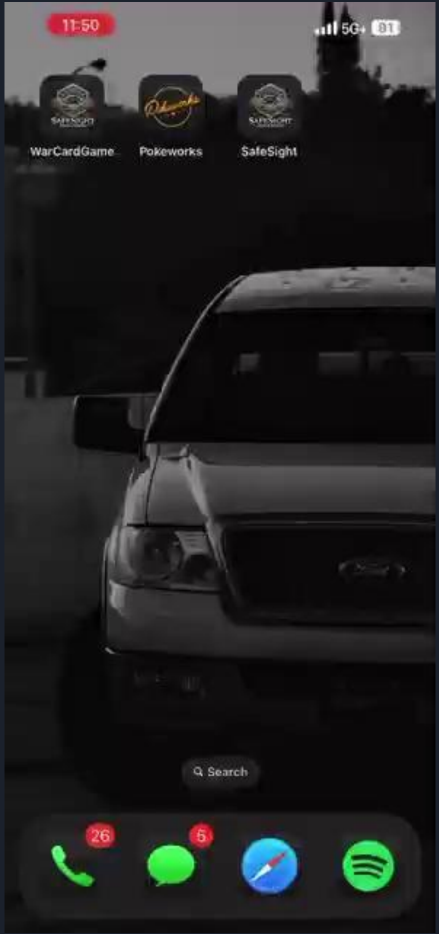
Software Diagram

- SafeSight will take many factors into account when determining distracted driving
- Factors will include (shown in chart):
  - Driver head angle
  - Traffic light color
  - Speed of car
  - Distance of car in in front of user



App Development

- **Original idea:**
  - Have 4 Views:
    - Have the user login using Apple ID at launch
    - Driver Report View
    - Live Camera & Gallery View
    - Profile Page View
- **Problem:**
  - Login with Apple ID feature requires Apple Developer Account ($100/yr)
- **Solution:**
  - Have the app tell the user to connect the SafeSight hotspot network upon startup instead of logging in

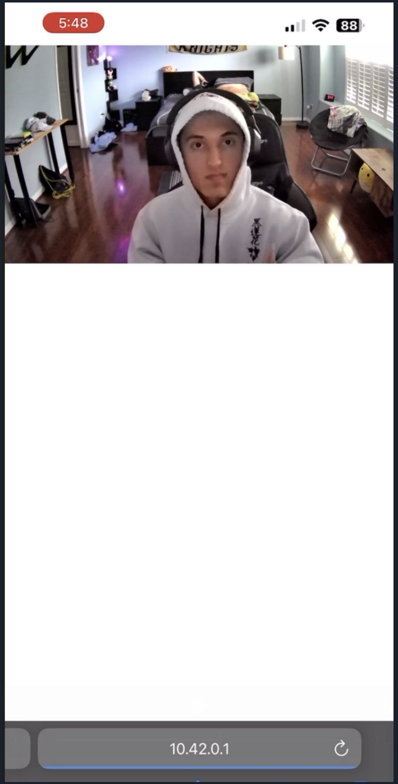


The Problem at Hand

- **Issue:**
    - Needed to figure out a way to send the pictures of distracted drivers over from the Pi to our iOS app
    - Came across one issue: iOS applications do not allow for bluetooth file transfer
- **Solution:**
    - Have the Pi put out a signal, act as a host with an IP address
    - Connect to that signal on the iPhone
    - Have the Pi point to a folder on the system
    - Send the Pictures over HTTP to the iPhone app and display them
    - Similar to a INSTA 360 or GOPRO camera

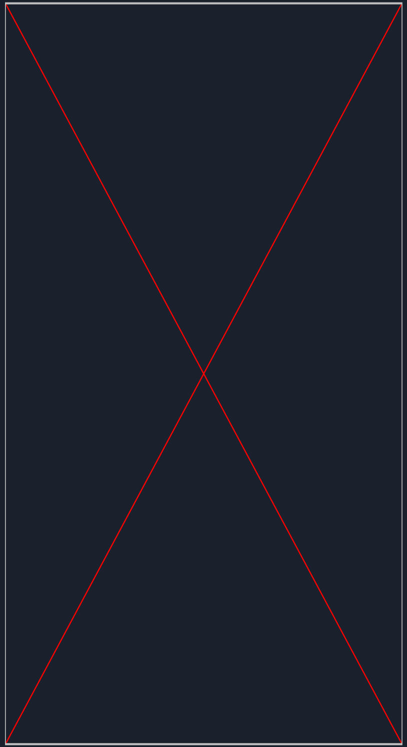
Solution: Host Over HTTP

- Pi connection established via Pi’s Hotspot IP address
- As of right now, the Pi takes a picture every time you open the “Live Camera Feed” view
- **Next step:** Configure the Pi to display all of the images of distracted driving to the app



Displaying Photos From Pi

- The photos of the distracted driving are shown from the Pi to the app in a gallery style
- This will allow the user to see how many times they were caught driving while distracted
- Essential for insurance companies and other companies like Uber, Lyft, etc.



What’s Next for Software?

- Develop a way to display the driver report in the app (possibly with a data table that refreshes after 10 trips)
- Get the live preview of the camera feed when connected to the app
- Set up the profile page for some settings or features (not sure if I am going to keep this page)
- Set up the CV to take a picture every time the driver is distracted at the wheel and store it inside the Pi’s picture folder.

Computer Vision Selection

Framework	Capabilities	Ease of Use	Speed	Accuracy	Best Use Cases
OpenCV	Comprehensive library for image/video processing, object detection, tracking, facial recognition, and machine learning integration	High (simple APIs)	Fast	High	Real-time applications involving color/shape labeling
TensorFlow/TensorFlow Lite	Advanced deep learning framework supporting neural networks, TPUs, dataflow graphs, and distributed computing. TensorFlow Lite enables deployment on mobile/edge devices	Moderate	Moderate	Very High	Deep-learning based object detection, facial sentiment analysis
Keras	High-level API for building neural networks with TensorFlow backend, simplifies model creation, training, and deployment. Supports integration with datasets like NumPy arrays and Pandas DataFrames.	Moderate	Moderate	Very High	Custom object detection tasks that require high precision
YOLO	Real-time object detection algorithm that processes images in a single pass through a neural network. Optimized for speed, but struggles with small/multiple objects due to grid-based architecture.	Moderate	Very Fast	High	Real-time application in surveillance, human posture detection, and self-driving cars
Scikit-Image	Filtering, segmentation, feature extraction, morphological operations, and geometric transformations.	High	Moderate	Moderate	Simple image processing tasks including basic object/face detection

Computer Vision Progress

Driver's Posture CV Model

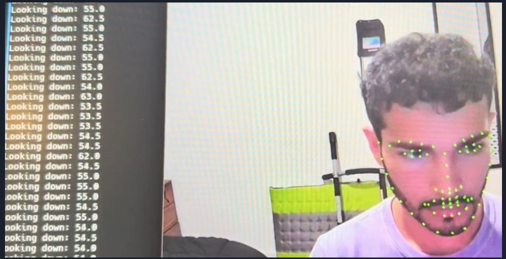
- Utilized Teachable Machine that uses tensorflow to create a model and export it as a Keras file to be used in a python script.

Problem

- Models from teachable machine were in need of much more training in order to obtain a working algorithm that was universal to all facial structures.
- Testing of Keras file generated from teachable machine. Was so selective in its training model that a simple change in color of a T-shirt would disrupt its operation of face posture.
- Decided that we needed much more raw data collection and it was unreliable since we did not have the ability to properly teach the computer vision model in the given time frame.

Solution

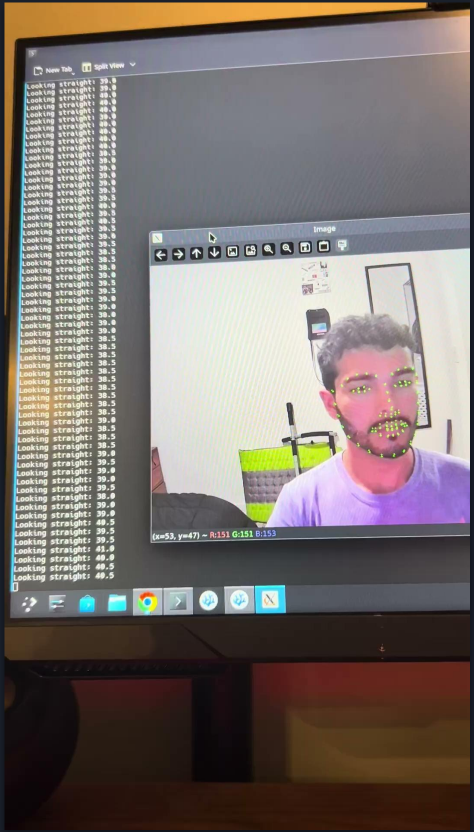
- OpenCV face detection and face angle library proved to
- Proposed solution was to use OpenCV face angle detection that would pickup on any person's facial structure and assume their head posture relative to the road by calculating angles in real-time based on their face posture.



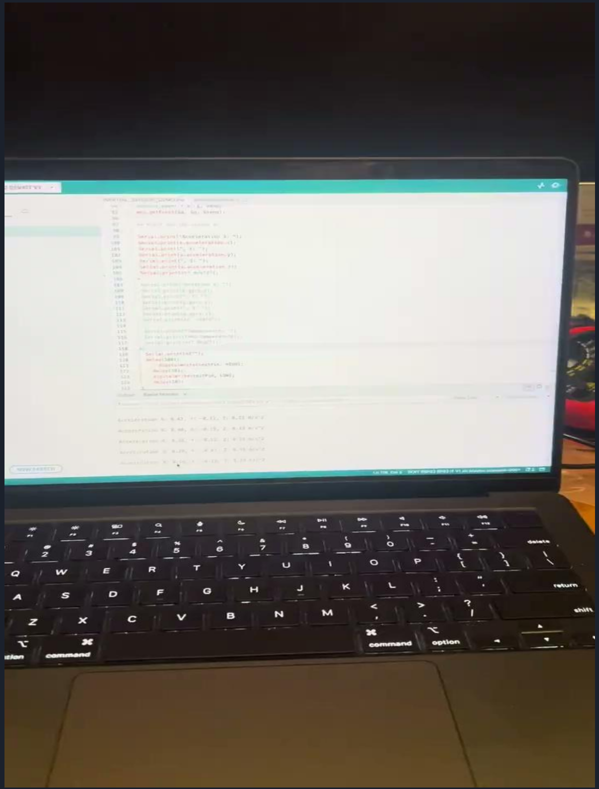
Face Angle CV

Functionality Testing - C4001 Radar

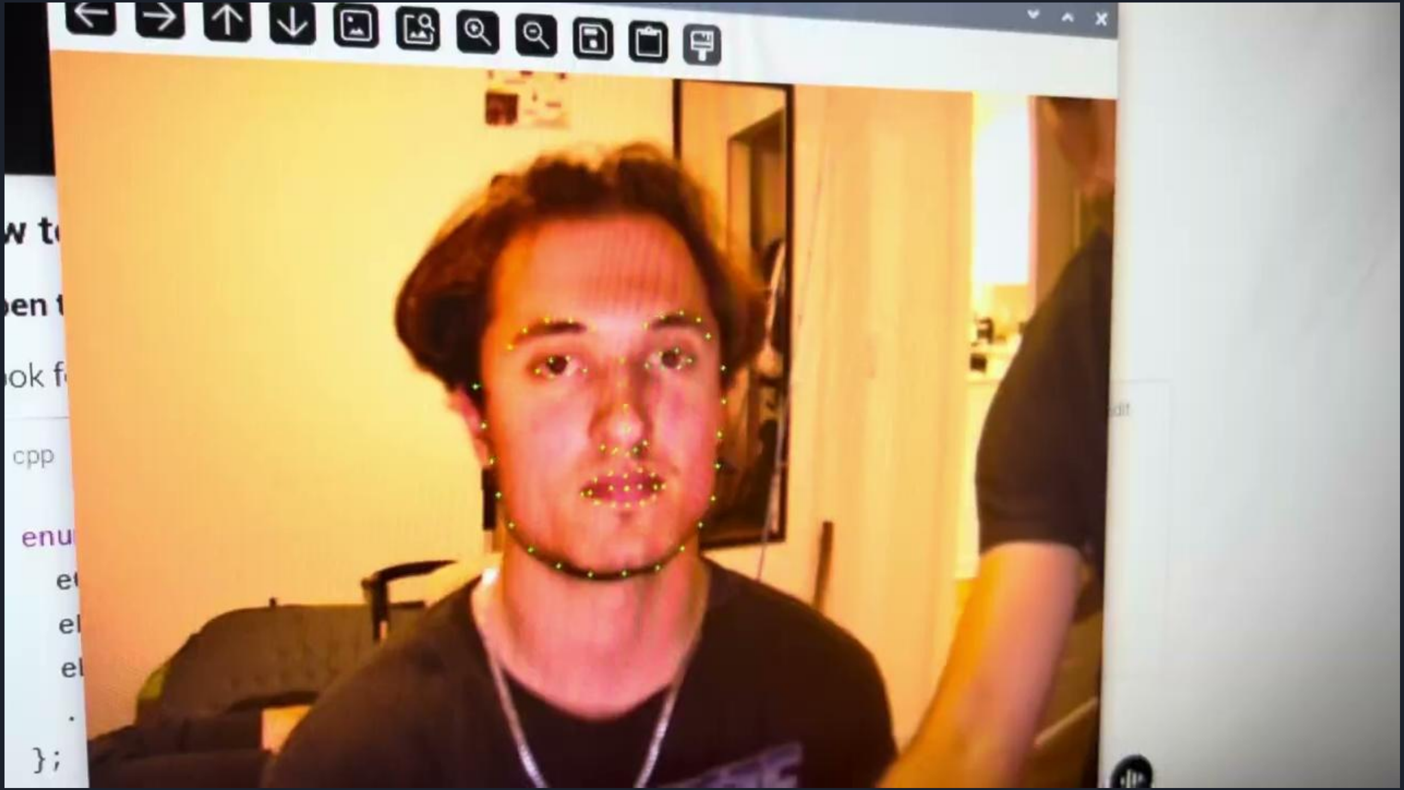
Functionality Testing - Raspberry Pi 5



Functionality Testing - MPU-6050 Accelerometer



Major Component Integration



BOM

Selection	Cost
Raspberry pi 5 8GB RAM + Cooler Kit	$140
Accelerometer Dev Board (Testing)	$12.95
C4001 Radar	$27.90
JLCPCB Order	$159.58
Digikey + LCSC Component Order	$92.37
Total Cost	$432.80

*USB Cameras and ESP-32 Dev board were pre-owned contributions to the project and are not included in the BOM

Line Item	Ordered	Available Qty	Backordered Qty	Item Number/ Description	Unit Price USD $	Amount USD $
1	3	3	0	**PART:** 565-EMVY6R3ARA102MHA0GCT-ND **DESC:** CAP ALUM 1000UF 20% 6.3V SMD **MFG** : UNITED CHEMI-CON (VA) / EMVY6R3ARA102MHA0G **COO** : JAPAN **ECCN:** EAR99 **HTSUS:** 8532.22.0020 ROHS3 COMP REACH UNAFFECTED 21-JAN-2025 **Mercury:** Cert on File. For more information contact Environmental@DigiKey.com	0.77000	2.31

Sales Amount	2.31
Shipping charges applied	4.99
Sales Tax	0.15
Total	7.45
	USD $

Summary

Merchandise Total	**$76.33**
Shipping Fee	**$18.19**
Total Discounts	**- $9.60**
Merchandise Discount	- $1.60
Shipping Discount	- $8.00
Total	**$84.92**
Paid Amount	**$84.92**

	Product	File Name	Order Number	QTY	Unit Price	Ext.Price
1	Solder Paste Stencil	SAFE_SIGHT_PCB7_2 0250912144136	SO12509126559	1	USD $3.00	USD $3.00
2	Solder Paste Stencil	SAFE_SIGHT_PCB8_2 0250912143444	SO12509126558	1	USD $7.00	USD $7.00
3	Solder Paste Stencil	SAFE_SIGHT_PCB4_2 0250912144313	SO12509126561	1	USD $3.00	USD $3.00
4	2-layer Bare Rigid Printed circuit board	SAFE_SIGHT_PCB4_2 0250912144313	Y4	5	USD $0.80	USD $4.00
5	2-layer Bare Rigid Printed circuit board	SAFE_SIGHT_PCB8_2 0250912143444	Y2	5	USD $11.85	USD $59.25
6	2-layer Bare Rigid Printed circuit board	SAFE_SIGHT_PCB7_2 0250912144136	Y3	5	USD $0.42	USD $2.10

Merchandise Total:	USD $78.35
Shipping:	USD $34.31
Shipping Discount:	-USD $10.00
Subtotal:	USD $102.66
States Sales&Use Tax:	USD $6.67
Import Taxes :	USD $50.25
Grand Total:	USD $159.58

Tax rates vary for different products; please refer to the tax details .

Project Gantt Chart