

FAMU FSU College of Engineering
Department of Electrical and Computer Engineering

Evidence Book

Team 312: Drowsiness-sensing Rear View Mirror

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Abstract

Hundreds of thousands of deaths occur every year due to drowsy driving. With assisted driving technology improving each year, reducing the tragedies of drowsy driving is becoming more likely. The drowsiness-sensing rear view mirror will enable car manufacturers to predict when the driver is sleepy and enable assistive driving features. A radar system inside the mirror records data from the driver. The radar emits a wave and calculates the driver's breathing rate and head tilt from the reflected wave. The device uses signal processing to extract these physical signals. Next, the data is fed into an algorithm which predicts if the driver is falling asleep due to changes in their body. A slower breathing rate and a driver's head tilting down for an extended period of time suggests they are getting drowsy. Once the algorithm estimates the driver is falling asleep, it alerts the vehicle's operating system to activate safe driving measures. To test the design, a chest belt was used to record breathing rate and head angle was observed directly . Also, tests were conducted at times when there is a high risk of feeling sleepy, such as at night. The mirror was able to detect drowsiness about a third of the time. Since every person has unique sleep patterns, personal calibration could be introduced in a future design to adjust for this. Also, other factors that indicate drowsiness, like heart rate, could improve the accuracy of the model.

Acknowledgement

Special thanks goes out to all involved in making this project come to fruition, including, Dr. Arigong, who provided the idea and the radar board which were essential for the initiation and development of our drowsiness detection rearview mirror project. We are also immensely grateful to Mr. Casamayor, our academic advisor, for his relentless support, guidance, and encouragement throughout this endeavor. Our appreciation extends to the Senior Design coordinators, Dr. Chuy and Dr. Hooker, for their invaluable insight and assistance during this process.

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Project Scope: Drowsiness Mirror

Project Description:

- Develop a drowsiness sensing rear view mirror which tracks eyelid movement to determine driver drowsiness to facilitate autonomous driving. Included in the system is a mmWave radar, which has a radio frequency transceiver and a microcontroller, which will be encased in a compact custom 3D printed rearview mirror. The hardware along with the algorithm developed will have low-power consumption; this will also extrapolate the eyelid movement data and convert it to sensory information.

Key goals:

- Develop algorithm which processes hardware data for drowsiness detection
- Create casing to house mmWave radar system and other necessary physical components
- Hardware is safe to use
- Tests show the prototype successfully detects drowsiness.

Deliverables to Sponsor

- Completed system with fully functional prototype.
- Technical report showing simulation, design, implementation, testing approach, and measured data
- System testing, analysis and recommendations for future extensions

Market:

- **Primary**
 - Car and truck manufacturers
 - Vehicle parts manufacturers
- **Secondary**
 - Drivers
 - Defense contractors

Assumptions:

- There is sufficient power for the radar.
- The driver is in the field of view of the radar system.
- Car has autonomous features.
- The rear view mirror is properly mounted and wired.

Stakeholders:

- Luke Forbis, Lucas Torres, Theodor Owchariw, Ben Covitz, Victor Bellera Tovar
- Dr. Arigong
- Car manufacturers
- Drivers in general

Customer Needs

Gathering Customer Statements:

The team met with the sponsor (Dr. Arigong) at the FAMU-FSU College of Engineering to gather customer statements. The team asked key questions to understand the scope of the project.

“What is the key goal of this project?”

- The device will scan the driver’s eyes and/or head, using a mmWave radar system, to determine if they are drowsy.

“Should the driver be notified that they are drowsy?”

- Yes, If the driver is drowsy, they should be alerted that the car’s autonomous system should take over the burden of driving.

“How far can we take the project?”

- An app could be created to track the data captured by the device.

“What technology do you want to be used to scan the driver’s face/head?”

- A millimeter wave radar system will be used to detect the changes in the drivers eyes.

“Who is the primary customer for this device?”

- Vehicle manufacturers that include autonomous systems in their products.

After noting these statements down the following interpreted needs were found:

Requirements:

- Need: Not Distracting
 - Requirement: The device’s method for notifying the driver of their drowsiness shall draw the minimum necessary attention to alert the driver of their drowsiness.
- Need: Vehicle Connectivity
 - Requirement: The device shall communicate the driver’s drowsiness levels with the vehicle’s autonomous system.
- Need: Components Housing
 - Requirement: Device shall have a proper fitting housing with necessary input/output holes which will attach to the mirror.
- Need: Computer connectivity

- Requirement: Device shall have the capability of connecting to a computer to enable data transfers and updates.
- Need: Drowsiness Detection
 - Requirement: Device shall have the capability to detect drowsiness in the driver.
- Need: Low Power
 - Requirement: Device shall affect Vehicle's overall power consumption by an insignificant margin.
- Need: Autonomy
 - Requirement: Device shall function without the need of manual user input and work passively.
- Need: Reasonably sized
 - Requirement: Housing for microcontroller and radar shall fit the majority of average-sized vehicles without hindering driver's overall visibility.
- Need: Output for Detection
 - Requirement: The system shall notify the user once the device determines that drowsiness has been detected.
- Need: Affordable Production Cost
 - Requirement: The project shall be created with a reasonable cost of materials to develop the device.
- Need: Microprocessor
 - Requirement: Device shall use a microprocessor for its drowsiness detection algorithm.
- Need: Battery Powered
 - Requirement: Device shall be powered through an external power source.
- Need: Radar
 - Requirement: Device shall contain a radar to propagate waves for eye/face detection.
- Need: Must Comply With Automotive Rear View Mirror Codes
 - Requirement: Device shall comply with the Federal Motor Vehicle Safety Standard (FMVSS)

Discussion:

The main need found is **drowsiness detection**. From our customer statements, the device needs the following components to detect drowsiness:

- Microprocessor
- Radar

Aside from the components needed, the device shall have a certain amount of ease of use for the customer including a mechanism for notifying the user which is why the following needs were added:

- Autonomy
- Not distracting
- Output detection

Given that the design will be used within a vehicle the needs take into account connections and overall electrical design which would function within an average car:

- Low power
- Vehicle connectivity
- Computer connectivity
- Battery powered

Additionally, the needs considered additional hardware concerns which would be required for the design:

- Affordable production cost
- Components housing
- Reasonably sized

Lastly, the design will have to adhere to the Federal Motor Vehicle Safety Standard (FMVSS). The FMVSS specifies design, construction, performance, and durability requirements for motor vehicles used in the U.S. The safety standards establish minimum performance requirements for manufacturers and the equipment used to make a vehicle. Standard No. 111 will be most relevant to this project

Target Values

Derivation of Targets/Metrics

For data collection, the value of interest is the distance from the driver to the sensor measured in millimeters. The range of 500 - 2000 mm represents a typical distance from the driver to a rear view mirror.

The desired mirror size was based on standard rear view mirror dimensions with additional thickness to house other components such as wires and indicators.

The board has an operating voltage of 5V, so this is a nonnegotiable target.

Low power consumption was a crucial need determined from our customer statements so the device should consume no more than 1W of power.

The algorithm must also satisfy a certain amount of success rate when determining if the individual is drowsy. Our target here is to create an algorithm which can successfully detect drowsiness upwards of 30% of the time.

Discussion of Testing

Many of our targets turned out to be binary metrics meaning it can be easily observed if the target is met for its intended function, such as alerting the driver and not being distracting. For other targets like the volume, the design would have to be initially measured inside of CAD software and be physically verified for the ideal dimensions using a measuring tape. An ammeter will be used to find the amount of current being supplied to the board for power calculations. There are many ways to test the accuracy of the device's ability to detect drowsiness that are loosely defined. This may include simulating drowsiness which is not always reliable. Thus, the final methods of testing drowsiness have yet to be determined.

Concept Generation

Overview:

Given the project scope being limited to a rear view mirror which detects drowsiness using a radar, the concepts that the team came up with were categorized into different groups to help break down the scope.

Body area for Radar Detection

CONCEPT 1: Detect heart rate

- Detect heart amplitude (M)
- Measuring contractions/expansions of heart (bpm) (H)

CONCEPT 2: Detect respiration frequency

- Frequency of inhales to exhales (M)
- Analyze amplitude and intensity of respiration (H)

CONCEPT 3: Detect eyelid closure

- Develop baseline for eyelids for each driver for calibration (M)
- Set condition for eyelid closure percentage which indicates drowsiness. (H)

CONCEPT 4: Detect head movement

- Swaying from side to side (M)
- A pattern of slowly falling down and quickly spiking back up (H)
- A state of being down for too long (M)
- Movement for looking at the phone (noise filtering) (H)
- Movement in a rhythm pattern signifying music being listened to (noise filtering) (H)
- Detecting a yawn (M)

CONCEPT 5: Detect body swaying

- Forward and backward movements (M)
- Side to side movement (M)

CONCEPT 6: Execute concepts 3, 4 simultaneously (H)

CONCEPT 7: Execute concepts 1, 2 simultaneously (H)

Algorithm

CONCEPT 1: Use the majority of data from the radar and use MATLAB for noise reduction and data analysis. (M)

- Once data is gathered from radar use MATLAB to filter out noise/ghost targets (H)
- Organize data to be useful in the algorithm with the corrected targets (M)

CONCEPT 2: Filter data using radar and use MATLAB to strictly analyze data. (M)

- Fine tune the microprocessor's code to filter out noise (M)
- Remove "ghost" targets (H)
- Further tune radar for precise data gathering (M)

CONCEPT 3: Utilize neural network to employ training data. (M)

- Using the human mind as a model with training data representing learned situations, the use of a neural network can teach the algorithm how to learn from past experiences. (M)
- Gather training data to be used in network i.e. (feed forward network) (M)
- Using training data of drowsy drivers such as head nodding, more frequent blinking, and drooping eyelids (H)

CONCEPT 4: Have state cases for noisy/noiseless situations

- Create parameters for when there is more noise, “blocking” more of the received signals if there is more noise present. If there is less noise, allow more of the signal to be received. Overfitting vs underfitting. (M)
 - Switch between said parameters depending on how ideal conditions are. This can be done after a threshold is surpassed. With this, phase noise, thermal noise, and the noise figure of different components can be isolated. (H)

CONCEPT 5: Create cases for different drowsiness states (awake, falling asleep, completely asleep)

- With whatever method is employed to determine drowsiness, this will account for the transition from awake to asleep. This will provide a different output to both the vehicle and driver. (M)
 - These can be developed further to provide more accurate measurements of total drowsiness. Three cases can become five or six cases for the transition into completely asleep. (M)

CONCEPT 6: Weigh different parameters (assuming multiple radar detection methods)

CONCEPT 7: Use Support Vector Machine (SVM) to classify human targets

- Use one case to test all objects that are trained to detect humans. All other objects will be outliers and will be classified as non-human. (M)

CONCEPT 8: Derive time delay from beat frequency (frequency difference between sent and received) (M)

- This time delay can be used to estimate target distance (this is because frequency signals are always sweeping through a frequency band). (M)
 - Impose parameters for these target distances, one for the maximum and minimum proximity to the radar. (M)

CONCEPT 9: moving target indicator filtering system

- Create an algorithm which will detect objects which are moving
- This will help to filter out “ghost” targets
 - Employ a neural network and training data to accomplish this (M)

CONCEPT 10: DSP System Toolbox for Receiver Signal Processing

- Run simulations of ideal/non-ideal conditions with visual spectrum data (M)
 - Can demonstrate if other elements of the algorithm (such as noise cases) are fully functional and still read proper distances/values. (M)

Indication to Driver

CONCEPT 1: AUDIO

- Buzzer
- Speaker with sampled audio (M)
 - Different buzzing dependent on drowsiness state

CONCEPT 2: VISUAL

- Blinking LED pattern
- LED Screen with custom symbol through mirror (M)
- Different RGB LED value dependent on drowsiness state (M)
 - Transition from white to red (AWAKE (white) -> FALLING ASLEEP (yellow) -> ASLEEP(red)) (H)

CONCEPT 3: A/V Combo

- An LED accompanied with a speaker to give both sound and visual indicators (M)

Indication to Vehicle

CONCEPT 1: AUDIO

- Buzzer
- Speaker with sampled audio

CONCEPT 2: VISUAL

- Blinking LED pattern

Mirror Casing Material

CONCEPT 1: Plastic

- 3D printing filament (M)
- Clear plastic (M)
- Old mirror casing
- Plexiglass casing

CONCEPT 2: Metal case

CONCEPT 3: Wood casing

CONCEPT 4: Plastic metal hybrid

CONCEPT 5: Plexiglass casing

CONCEPT 6: Rubber casing

- Hard rubber (M)
- Soft rubber (M)

CONCEPT 7: Carbon fiber

- Carbon fiber outer casing
- Entirely carbon fiber

CONCEPT 8: Variation of material with internal rubber stabilizers for the mm radar (M)

Testing environment

CONCEPT 1: Use members from the team who are fatigued to test prototype on

CONCEPT 2: Test design inside of a car with the ignition off and in park

CONCEPT 3: Test design in a controlled setting which replicates inside of car

- Replicate setting with appropriate distance between radar and driver. (M)
- Using controlled environment test variables within the driver such as height and clothing. (M)

Testing method

CONCEPT 1: Simulate specific conditions via the simulink model in MATLAB

- Create simulink blocks that with parameters from the matlab workspace (M)
 - Utilize mixers to create and test dynamic range limitations (M)

CONCEPT 2: Observe the levels of drowsiness on a scale

CONCEPT 3: Observe drowsiness levels throughout the day

CONCEPT 4: Observe a binary state of drowsy vs non-drowsy

- At any one point, can the device determine whether the driver is drowsy or not, after a certain threshold. (M)

CONCEPT 5: Observe head movement

- Take multiple data points of the same and or similar head movements and plot them in a range to have a broader range of accuracy for detection. (H)

Summary

In this document, all the ideas to produce a drowsiness-sensing rear-view mirror are explored and categorized according to the specific facet of the problem. These are body area for detection, type of algorithm to employ for drowsiness detection, the drowsiness indicators to the driver and the vehicle's autonomous system, testing environment, and method of testing for drowsiness. It is assumed that the vehicle has an autonomous system, so the indicator to the vehicle is for proof that the autonomous system knows the driver is drowsy. The primary tools for concept generation were general brainstorming, biomimicry, anti-problem and reading some technical papers to get an understanding of how this problem had previously been approached. Around 100 total concepts of which, 40 were medium fidelity and 15 were high fidelity. The high fidelity concepts are focused mostly in the "algorithm" and "body part for radar detection" sections as these are the most important parts of the design. More high fidelity concepts will need to be developed for the two testing sections in the future after more research and development. There are medium fidelity concepts are more evenly distributed throughout each section.

Concept Generation Tools:

Most concepts were developed over multiple brainstorming sessions, however, the above concepts were found using specific concept generation tools:

Biomimicry:

- Taking into account the design of the human brain, the idea for using a neural network was proposed. Aside from this, not many concepts were found using this tool except for taking into account the limitations found within echolocation.

Forced Analogy:

- This tool was useful when coming up with algorithm concepts. One of the random words the group listed was 'tree' and using a forced analogy the team thought of using neural networks for the algorithm of our design.

Anti-problem:

- For radar detection the team listed the worst ways to detect drowsiness before coming up with the concepts detailed below. For example, the team thought about detecting clothing, headwear, hair, (noise) etc. The actual solutions to detecting drowsiness would avoid these such as detecting heart rate frequency which removes irrelevant factors.
- Some of the mirror casing material concepts were found using this tool. The idea was to list materials that would cause the most issues in the design such as wood and thus spur the team with better ideas.

detect drowsiness, alert the driver of their drowsiness, and not be distracting to the driver. In the Performance category, the requirements are: high efficiency, affordable cost, and low power consumption. For Design Characteristics, the requirements are: 1-way mirror casing, autonomy, and reasonably sized. These customer requirements encapsulate the need for a device to detect drowsiness speedily and efficiently to prevent accidents from occurring. To meet these customer needs, the engineering requirements include a radar and microprocessor for implementation, battery power, a rearview mirror casing for housing of components, speed and accuracy of detection, and the indicators of drowsiness to the driver and the vehicle.

The numbers 1,5,9 indicate how strong the relationship is between customer and engineering requirements, with 1 representing weak relationships, 9 representing strong relationships and 5 representing moderate relationships. Each requirement has a weight to illustrate its importance to the design of the device. These weights are multiplied with the relationship values to determine its technical importance, which is then normalized to understand the relative weight of each engineering requirement. From the quantitative results of the HoQ, the microprocessor is the most important aspect of the design followed by the radar and indicators to the driver and vehicle, respectively. However, speed and accuracy for detection are arguably much more important than the indicators to the driver and vehicle in reality. The top triangular table details the strength of correlation between each of the technical requirements. A “+” indicates a positive correlation while a “-” indicates a negative correlation; a blank space implies no correlation.

Mirror Casing Material

Pugh Chart

Cost - Money to produce

Time to produce - Time to produce

Weight - Weight of completed casing

Durability - How durable will the casing be to stress

Difficulty to manufacture - How difficult will it be to produce

		Old mirror Casing	Plastic Casing	3D printing filament	Plexiglass casing	Hard rubber	Soft Rubber	Carbon fiber
Cost	6	-	-1	+1	-1	-1	-1	-1
Time to Produce	7	-	-1	-1	-1	-1	-1	-1
Weight	2	-	0	+1	-1	+1	+1	+1
Durability	7	-	+1	-1	+1	+1	-1	+1
Difficulty to manufacture	9	-	+1	+1	-1	-1	-1	-1
Score		-	3	3	-15	-13	-27	-13
Continue?		Yes	Yes	Yes	No	No	No	No

Table 1: 1st Mirror Housing Pugh Chart

		Old mirror casing	Plastic Casing	3D printing filament
Cost	6	-	-1	+1
Time to Produce	7	-	-1	-1
Weight	2	-	0	+1
Durability	7	-	+1	-1
Difficulty to manufacture	9	-	+1	+1
Score		-	3	3
Continue?		No	No	No

Table 2: 2nd Mirror Housing Pugh Chart

Algorithm

For the Algorithm criteria both the **Time Complexity** and the **Expected Effectiveness** were determined to be the most important criterias with the ladder being very slightly more crucial. This is because the design would need to detect drowsiness fast but also effectively since, detecting drowsiness 100% of the time slowly is just as undesirable as detecting drowsiness incorrectly very quickly.

Pugh Chart

Required Training Data - Data necessary to train the algorithm

~Time complexity - Assumed time complexity

Time to implement - Time it will take to write the code

Expected effectiveness - How well the code is expected to work

		Concept 1 (matlab)	Concept 2 (micro)	Concept 3 (AI)	Concept 4	Concept 8	Concept 9
Required Training Data	6	-	0	+1	0	0	0
~Time Complexity	8	-	+1	-1	-1	+1	-1
Time to Implement	6	-	-1	-1	-1	-1	-1
Expected Effectiveness	9	-	0	+1	+1	+1	+1
Score		-	2	1	-5	11	-5
Continue?		No	Combine	Combine	No	Combine	No

Table 3: Algorithm Pugh Chart

Indicator to Vehicle

For the indication to vehicle meaning the indication that will notify if the design is working properly, the most vital aspect is effectiveness. Note that the criteria here have different weights and values than the indication to driver criteria below because of the different perspectives taken.

Pugh Chart

Effectiveness - How effective the concept will be

Complexity to implement - Complexity of implementing concept

Cost - Cost to implement

		Audio buzzer	Speaker with sampled audio	Blinking LED Pattern
Effectiveness	6	-	-1	+1
Complexity to implement	6	-	-1	0
cost	3	-	-1	0
Score		-	-15	6
Continue?		No	No	Yes

Table 4: Indicator to Vehicle Pugh Chart

Indication to Driver

The driver indication has to be foremost **effective** since once the design detects drowsiness it needs to alert the driver properly as soon as possible. However, the notification should not be distracting because it might successfully alert the driver but remove his concentration while driving, leading to more danger.

Pugh Chart

Effectiveness to alert driver - How effective will the concept be to alert the driver

Complexity to implement - How complex will it be to implement

Cost - How much will it cost to implement

Not distracting - How non distracting is the concept

		Different RGB LED value dependent on drowsiness state	LED Screen with custom symbol through mirror	Speaker with sampled audio
Effectiveness to alert driver	9	-	+1	+1
Complexity to implement	6	-	-1	-1
Cost	6	-	-1	-1
Not Distracting	8	-	-1	+1
Score		-	-11	5
Continue?		Combine	No	Combine

Table 5: Indicator to Driver Pugh Chart

Testing Environment

As can be seen, effectiveness is the most important factor in a testing environment. This is mainly because if the testing environment is not effective it can lead to poor development of the design as a result of inaccurate results. A close second was the resources. The least important factor in the testing environment is time.

Pugh Chart

Effectiveness - How effective will test be

Time - Time necessary to test

Resources - Necessary resources to test

		Inside car	Replicate car
Effectiveness	7	-	-1
Time	6	-	-1
Resources	7	-	-1
Score		-	-20
Continue?		Yes	No

Table 6: Testing Environment Pugh Chart

Testing Method

Pugh Chart

Effectiveness - How effective is the testing method

Implementation Difficulty - How difficult will it be to test

Time - How long will it take to test

Controllability - How easily replicable will it be in further testing sessions

		Binary state of drowsy vs non-drowsy	Levels of drowsiness on scale	Drowsiness levels during day
Effectiveness	9	-	+1	+1
Implementation Difficulty	7	-	-1	-1
Time	6	-	0	-1
Controllability	8	-	-1	-1
Score		-	-6	-12
Continue?		No	Yes	No

Table 7: Testing Method Pugh Chart

Body area for Radar Detection

Radar detection requires new factors to consider such as the visibility of the body part being detected. Regardless, the effectiveness of the radar would be highly valued as would the time it would take to detect a set body part.

Ranking Criteria

Effectiveness - How well will body area be for detection

Time - How long will it take to detect

Simplicity - How straightforward will it be to detect this body part

Visible - How frequently visible will this body area be while driving

	Effectiveness	Time	Complexity	Visible	Product	4th root	Normalize
Effectiveness	1	1.429	1.176	2	3.34	1.352	0.331
Time	0.7	1	1.333	1.25	1.164	1.039	0.254
Simplicity	0.85	0.75	1	1.25	0.8	0.946	0.231
Visible	0.5	0.8	0.8	1	0.32	0.752	0.184

Table 8: Ranking Criteria for Best Body Area to Detect

AHP

Effectiveness - How effective is this concept

Time - How much time will it take to detect this concept

Simplicity - How straightforward will it be to implement this concept

Visible - How visible is this concept for the radar to detect

		Detect head movement	Detect respiration frequency	Detect eyelid closure	Detect heart rate	Detect body swaying
Effectiveness	0.331	4	8	9	6	3
Time	0.254	8	6	6	6	4
Simplicity	0.231	8	6	5	6	9
Visible	0.184	6	8	4	8	9
Score		6.308	7.03	6.394	6.368	5.744
Normalized Score		0.198	0.221	0.201	0.2	0.18

Table 9: 1st AHP for Best Body Area to Detect

		Detect head movement	Detect respiration frequency	Detect eyelid closure	Detect heart rate	Detect body swaying
Effectiveness	8	-	+1	+1	+1	-1
Time	7	-	-1	-1	-1	0
Simplicity	6	-	-1	-1	-1	-1
Visible	7	-	+1	-1	+1	+1
Score		-	2	-12	2	-7
Continue?		Yes	Combine	No	Combine	No

Table 10: 2nd AHP for Best Body Area to Detect

		Detect head movement	Detect respiration frequency + heart rate
Effectiveness	8	-	+1
Time	7	-	-1
Simplicity	6	-	-1
Visible	7	-	+1
Score		-	2
Continue?		Combine	Combine

Table 11: 3rd AHP for Best Body Area to Detect

Final selections:

1. **Mirror Casing Material:** 3D printing filament
 - Given that difficulty to manufacture is the criteria with the highest weight, using a **3D printing filament** for the rear view mirror casing is the best option. The improved cost and weight were both taken into account to come to this conclusion.

2. **Algorithm:** Concept 2 + Concept 3 + Concept 8
 - The **Concepts 2, 3, and 8** were chosen and combined since they can be used together to accomplish a better result. For instance, concept 2 details the use of a microprocessor to filter the data for radar detection; however, using the microprocessor for preprocessing in tangent with the AI would achieve a more desirable outcome. Note that the last concept was also chosen specifically for its time complexity but it depends on if the team decides on detecting heart rate.
3. **Indication to vehicle:** Blinking LED Pattern
 - Notifying that the design is working requires less detail than indicating to the driver that he/she is drowsy. This is the reason why a **Blinking LED Pattern** proved to be the best option due to its simplicity to implement and effectiveness to alert. The audio sample had a significantly lower score compared to an audio buzzer; therefore, the clear choice was obvious in this case.
4. **Indication to driver:** Different RGB LED value dependent on drowsiness state + Speaker with Sampled audio
 - This Pugh matrix showed the LED screen was too complex to implement in addition to its higher cost, making it a subpar choice. The combination of a **RGB LED** value and a **speaker with sampled audio** was chosen due to the need for its effectiveness to output variable levels of drowsiness.
5. **Testing environment:** Inside Car
 - Given the availability and effectiveness of using the inside of a car for our testing environment, this concept was chosen. Using a replica of the testing environment (the front seat of a vehicle) proved to be too complicated and time consuming for our project. As long as the radar can be tested in a similar environment there would be no reason to choose the ladder option.
6. **Testing method:** Levels of drowsiness on scale
 - Based on the indication to the driver being a variable i.e. the RGB LEDs, the correct decision here is to have the testing method be on a scale. This contradicts the Pugh matrix for this concept; however, for both of these concepts to work, this would have to be our testing method.
7. **Body area:** Respiration frequency +Heart rate + Eye closure
 - Using the Analytical Hierarchy Process **Respiration frequency** was found to be the best choice, however, this alone was not sufficient to come to a final selection. This is because most of the scores for the other concepts are very close to one

another. As a result, Pugh matrices were evaluated for the same concepts to come to a more reasonable conclusion.

- Using the Pugh matrices for body area, detecting **Respiration frequency + Heart rate + Eye closure** is best because of their expected effectiveness and detection time. Using only one concept would lead to less effective results such as only considering heart rate. Studies show that heart rate decreases while driving drowsy but using this variable alone would not be as effective as evaluating multiple parameters at once specially considering the simplicity of analyzing head movement and in the extreme case ‘nodding off’.

Spring Project Plan

Mirror Housing

Jan 9th: Progress made on software design
Feb 12th: Review 1st completed digital draft
Feb 19th: Review 2nd draft before starting to print
Feb 26th: Present first printed case to team for review
March 4th: 2nd printing presentation
March 11th: 3rd printer design review
March 25th: Final design before presentation

Hardware

Jan 31st:

- Finalizing pins/ports

Feb 7th:

- Testing individual components
- Find power source

Feb 7th - 21st :

- Interface I/O w/ Matlab
- Wiring diagram
 - Find perf board create design on it

Mar 6th:

- wiring/soldering
- Assemble prototype

Mar 8th:

- Test design

Software

- Algorithm Draft 1 Mar 4th
 - Feb 5th:
 - Range mapping - velocity
 - Finding biometric targets
 - Feb 12:
 - Research algorithms from jonathan
 - Feb 19:
 - Lower level pseudocode
 -
 - Extract head signal
 - Decision making pseudocode
 - Implement binary decision for head code

- Test
- Algorithm Draft 2 (heart or lungs) Apr 2nd
 - Finding biometric targets
 - Research algorithms from jonathan
 - Lower level pseudocode
 - Extract heart/lung signals
 - Decision making pseudocode
 - Implement decision code
- Bayesian Network 1st Iteration Apr 17
- Bayesian Network 2nd Iteration Apr 23

General

January: Safety Consult

Feb 9th: VDR4

Feb 16th: Team Photos

Mar 1st: Website Update 1 due

March 29th: VDR5

Apr 4th: Design Day

Apr 25th: Final Demonstration

Apr 26th:

- Evidence Book due
- Website Update 2 due
- Scholarship in Practice due

CHAPTER 2

Final Detailed Design Report

I. Introduction

Given the frequency of accidents due to drowsy driving, how can we alert drivers when they get too drowsy and improve upon current autonomous safety features to prevent further accidents?

Driving, a necessity for many, can be very dangerous on any given day. It does not matter how careful one is driving, another person on the road may not be. This is also exacerbated by the toll of day-to-day responsibilities. This is significant because driving drowsy will statistically lead to more accidents, and thus, more deaths. To address this issue, there should be a way to detect drowsiness in a driver and allow their vehicle's autonomous safety features to take over if they are getting too drowsy to drive.

Project Description:

Develop a drowsiness-sensing rear view mirror that observes the driver and tracks their drowsiness levels to facilitate autonomous driving. Included in the system is a microcontroller with a built-in mmWave radar and a radio frequency transceiver to be encased in a compact custom rearview mirror.

Requirements:

The design has to detect drowsiness but it also has to work as a rearview mirror. Furthermore, the design would have to meet the following requirements:

- The device shall affect the Vehicle's overall power consumption by an insignificant margin.
- The device shall function without the need for manual user input and work passively.
- Housing for the microcontroller and radar shall fit the majority of average-sized vehicles without hindering the driver's overall visibility.
- The system shall notify the user once the device determines that drowsiness has been detected.
- The device shall communicate the driver's drowsiness levels with the vehicle's autonomous system.
- The project shall be created with a reasonable cost of materials to develop the device.
- The device shall use a microprocessor for its drowsiness detection algorithm.
- The device shall be powered through an external power source.
- The device shall contain a radar to propagate waves for eye/face detection.

- The device shall comply with the Federal Motor Vehicle Safety Standard (FMVSS)

II. Selected Concept

The selected design was chosen after a brainstorm of every possible solution discussing and breaking down everything from material design, coding, detection methods, and best methods of verifying success. After conceptualizing the many possible solution cases for this project, the following were selected as the final concepts to realize this design. 3D printing filament was chosen as the mirror casing material due to its accessibility and cheap cost to produce. A simple LED will be used to indicate the driver's drowsiness to the autonomous system of the vehicle. An RGB LED in addition to a single-tone buzzer will notify the driver of their drowsiness and that some assistive autonomous driving feature will take over. These are both cheap and effective options to meet their respective customer needs. To detect drowsiness, the device will be closely monitoring the heart, lungs, eyes, and head. The lungs and heart will be the primary body parts for detecting drowsiness due to their size and constant visibility while the eyes and head will be secondary to increase detection accuracy.

For collecting and processing the required physical data, the POSITION2GO board will be employed. With its mmWave Radar sensor, analog body data can be recorded and converted to usable digital data. From there, MATLAB will be used to clean the data and implement it into a drowsiness-detection algorithm. The MATLAB environment was chosen due to its familiarity among the team and the board's ability to run MATLAB code. The drowsiness-detection algorithm will detect the beat frequency of the heart as well as the respiration frequency of the lungs and compare that data with its training data to determine if the driver is drowsy. Machine learning may be used for more accurate application of the training data. After assembly of the prototype, the experimental tests will be performed in a stationary, turned-off car to mirror the real-world scenario. Lastly, the testing method will involve testing team members and other participants at different points throughout the day to observe their drowsiness levels. To collect more data, participants will attempt to mimic drowsiness to test the accuracy.

III. Preliminary Design

The mirror housing will be designed in 3D modeling software and 3D printed at FSU's Innovation Hub using their selection of filament types. The casing will have an area to securely hold the POSITION2GO board inside. The placement will include space for connections to the board, such as the cable to upload the code and the wires for the audio/visual indicators. The case will have a split open design to allow for quick adjustments for testing and simplicity for monitoring connection.

Below are the previous and current iterations of the device's functional decomposition. The updated model removes the ADC block as the built-in microprocessor and radar will automatically do these processes and will not need to be implemented manually. Overall most of

the functional decomposition has stayed the same. Additionally, a high-level breakdown of the selected components to realize the design is shown below the functional decompositions.

Initial High-level Code Breakdown:

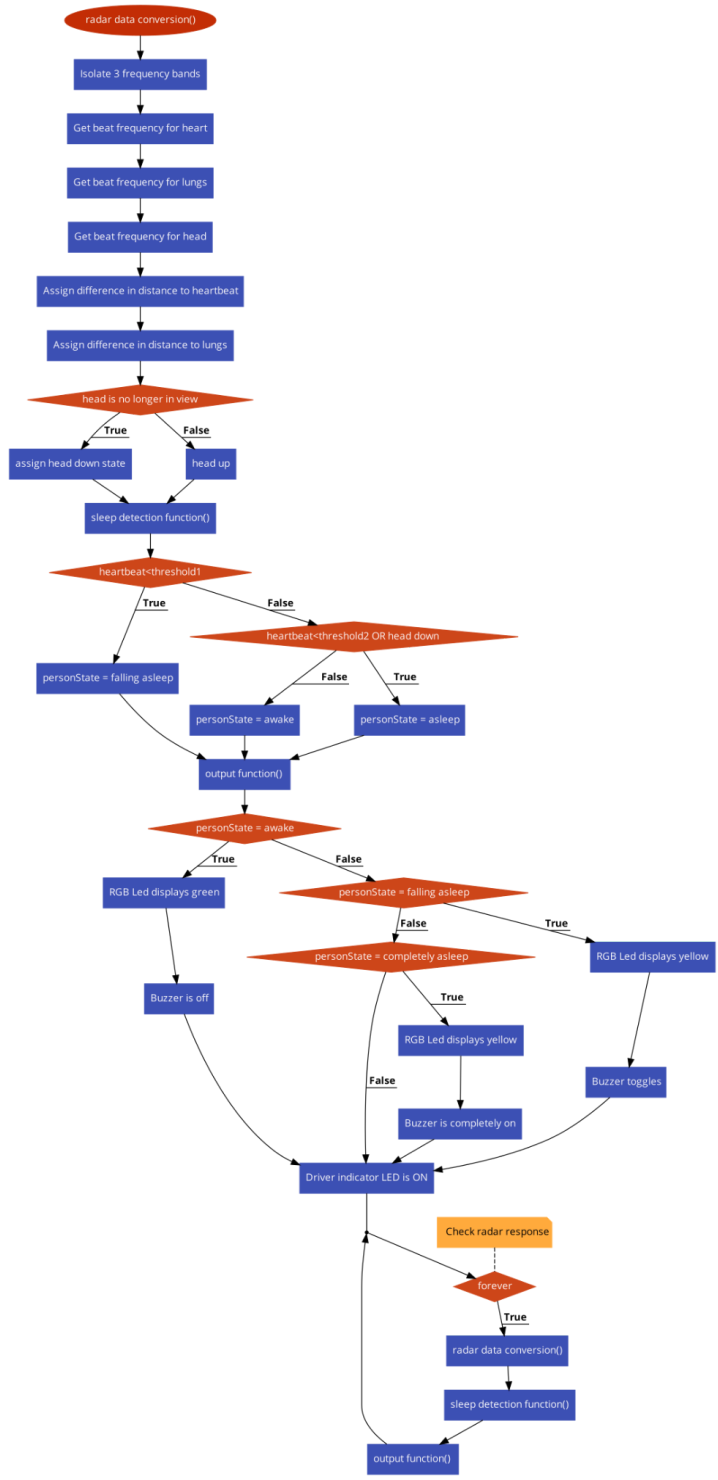


Figure 2: High Level Pseudocode

IV. Revisions

Throughout the duration of this project, several issues were encountered that required various aspects of the project to be redesigned or changed completely. The biggest issue was the delay caused by the signal processing challenges of getting a reliable range measurement and extracting biometric information. The delay forced the design to focus primarily on the driver's head position with a secondary emphasis on the breathing rate. Another significant problem was the inability to interface with the I/O pins on the POSITION2GO board. Manufacturer documentation listed I/O pins on the board and implied they could be used. However, there was no supporting documentation found nor available online resources that explained how to interface with these I/O pins, making the desire to include LEDs and buzzers an apparent impossibility. To make up for this, the declaration of “drowsy” or “not drowsy” will be output to MATLAB's console as well as a notification that the vehicle's system has been alerted.

Other issues involving the production of the mirror casing led to several redesigns. Originally, the plan was to create a mirror casing that could be split open from the middle to allow for rapid prototyping and testing, but this proved too difficult to produce. A simpler housing was created where the mirror glass could be slid in and out quite easily to allow for changes to the board. Additionally, the available mirror glass for the design has a metallic backing, meaning it will reflect a portion of the transmitted radar wave back before it reaches the driver. This would create inaccurate readings so a revision was made to keep the part of the mirror containing the radar uncovered by any glass so it can reliably send and receive waves. Lastly, the decision making process was changed from the original plan to instead use a Bayesian Network approach. This approach was deemed more reliable and accurate given that each factor of drowsiness has a respective probability associated with it to give a more precise prediction of drowsiness. The Bayesian Network uses the probabilities of known events to calculate the posterior probability of drowsiness. It is made up of five nodes with multiple possible states denoting time spent driving, decrease in breathing rate, head position, time of day, and drowsiness.

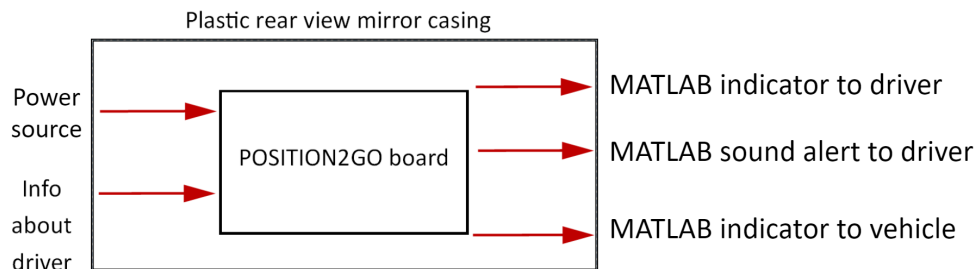


Figure 3: Finalized Component Breakdown

Revised pseudocode

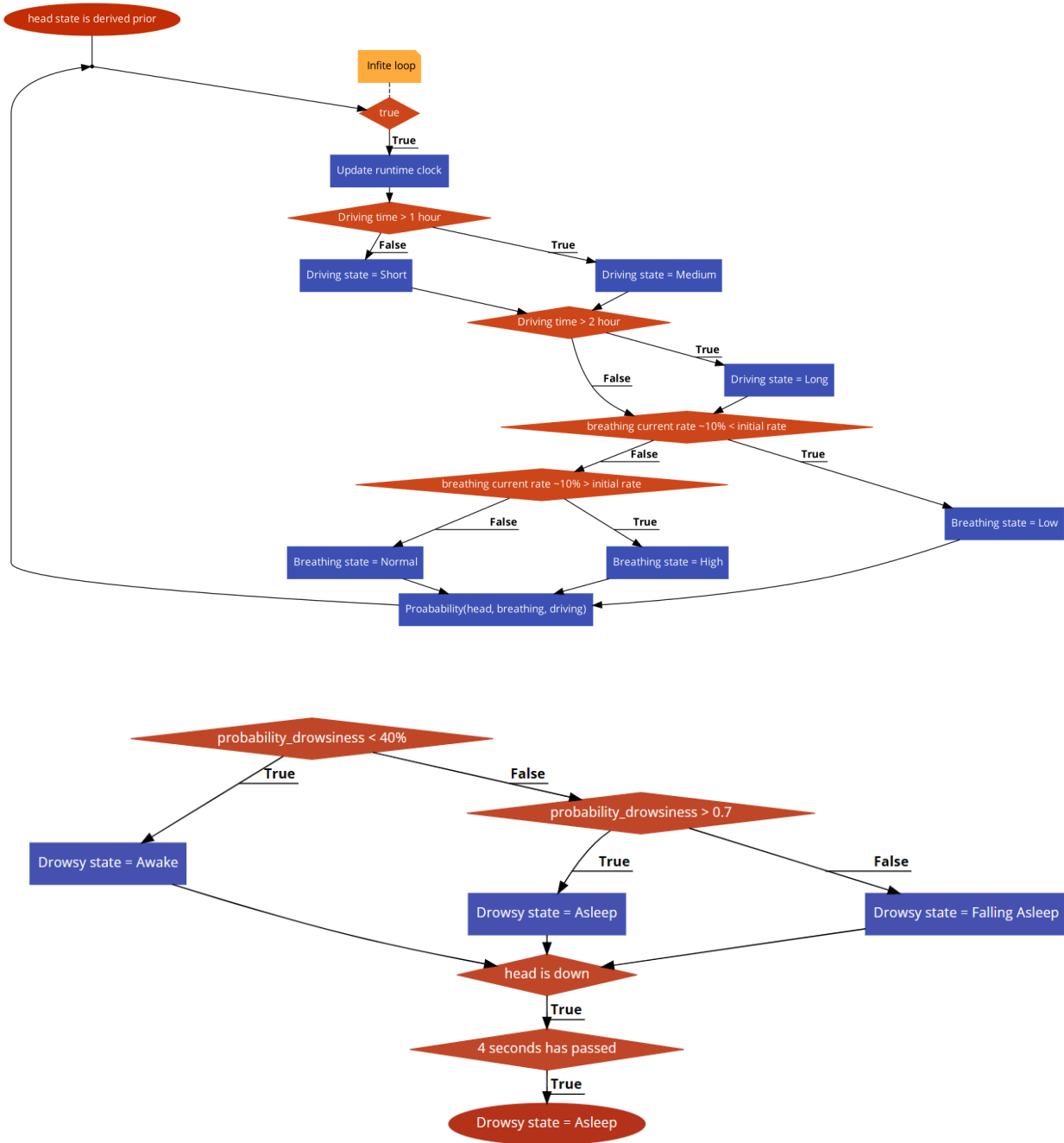


Figure 4: Revised High Level Pseudocode

V. Final Design + Conclusion

This project aims to address the issue of drowsy driving accidents by creating a drowsiness-sensing rear view mirror. The initial design listed above was modified to address the various issues that arose over the course of the project. The final design concept will still use a compact rear view mirror created with a 3D printing filament. Also, the POSITION2GO Board used to capture the driver's biometrics and determine drowsiness will be housed within the mirror casing. Though, the radar will not be completely covered by the mirror glass to ensure viable operation of the transceiver. The MATLAB environment will be used to process the received radar data to extract information from the driver. Additionally, MATLAB will be used to create the Bayesian network to determine drowsiness and output alerts to the driver via the console and the sound function. The design will be tested in a stationary car to mimic a real-world environment. Furthermore, testing participants will be observed throughout the day to see how their drowsiness levels fluctuate or they will pretend to be drowsy if they can not be observed during their most drowsy time of day. A respiratory belt will be used to collect breathing data while the head position can be easily observed during testing. All in all, the design integrates advanced sensor technology, data processing, and artificial intelligence to create an effective solution for protecting those affected by drowsy driving.

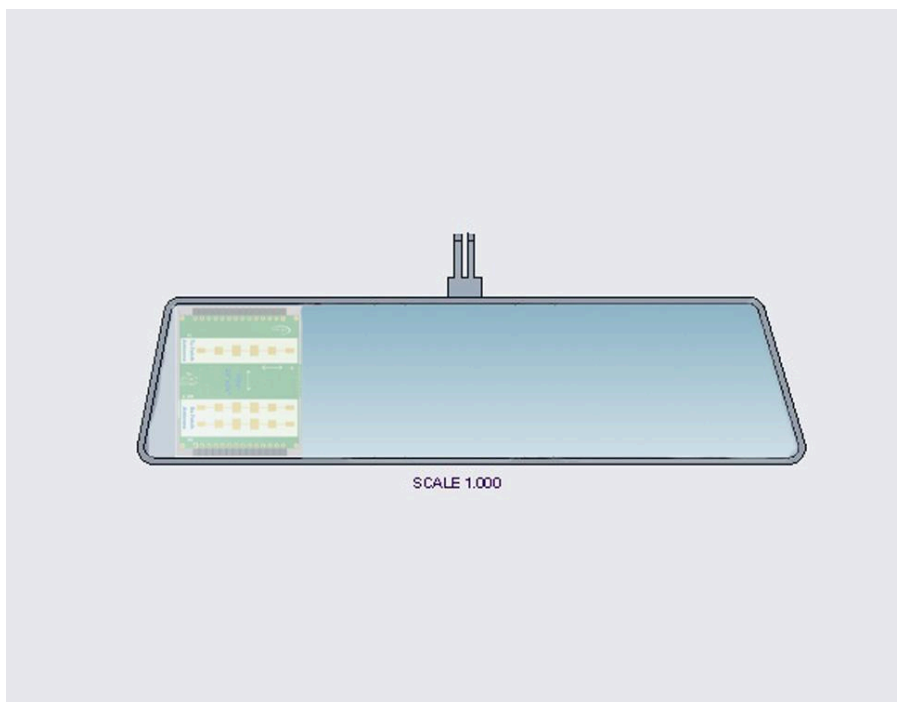


Figure 5: Final Device Rendering

Testing & Validation

Test Writer Theodor Owchariw			
Test Case Name	Head Nodding 0	Test ID #:	00
Description	This will test the effectiveness of detecting drowsiness given two controlled variables (time, respiration) and one experimental variable (head nodding). How accurate can the algorithm detect drowsiness given multiple sample of head positing and will the parameters for the other variables function as expected for detecting drowsiness.	Type	Test
Tester Information			
Name of Tester	Victor Bellera Tovar, Theodor Owchariw, Lucas Torres	Date	4.4 .24
Hardware/Software Ver.	Position2Go, MATLAB	Time	3:30 P M

Setup		Sitting in car with mirror mounted on windshield slightly above head of tester, with mirror angled slightly downward. Laptop will be open with MATLAB to confirm testing results. Run program, wait 10 seconds for initialization then begin testing procedures.					
Step	Actions	Expected Results		Pass	Fail	N/A	Comments
1	Head: Up Respiration: Low Time: Short	Falling Asleep		Y	N		
2	Head: Up Respiration: Low Time: Medium	Falling Asleep		Y	N		

3	Head: Up Respiration: Low Time: Long	Falling Asleep		Y	N		
4	Head: Up Respiration: Normal Time: Short	Awake		Y	N		Awake for 3 samples
5	Head: Up Respiration: Normal Time: Medium	Awake		Y	N		Awake Consistent
6	Head: Up Respiration: Normal Time: Long	Falling Asleep		Y	N		Condition might be changed. Probably too high
7	Head: Up Respiration: High Time: Short	Awake		Y	N		
8	Head: Up	Awake		Y	N		

	Respiration: High Time: Medium						
9	Head: Up Respiration: High Time: Long	Awake		Y	N		
1 0	Head: Down Respiration: Low Time: Short	Falling Asleep		Y	N		In future, change probability to be 0.7
1 1	Head: Down Respiration: Low Time: Medium	Asleep		Y	N		Took 2 samples
1 2	Head: Down Respiration: Low Time: Long	Asleep		Y	N		Took retry since board fell out of position
1 3	Head: Down Respiration: Medium Time: Short	Falling Asleep		Y	N		Took extra loop to show falling asleep
1 4	Head: Down Respiration: Medium	Falling Asleep		Y	N		

	Time: Medium						
1 5	Head: Down Respiration: Medium Time: Long	Asleep		Y	N		
1 6	Head: Down Respiration: High Time: Short	Awake		Y	N		Took extra sample to change probability
1 7	Head: Down Respiration: High Time: Medium	Falling Asleep		N	Y		Took 3 extra samples to change to falling asleep
1 8	Head: Down Respiration: High Time: Long	Falling Asleep		Y	N		
Overall Test Result							Accuracy: 16/18

Table 12: Testing and Validation Sheet 1

Test Writer Theodor Owchariw

Test Case Name	Head Nodding 1	Test ID #:	01
Description	This will test the effectiveness of detecting drowsiness given two controlled variables (time, respiration) and one experimental variable (head nodding). How accurate can the algorithm detect drowsiness given multiple sample of head positing and will the parameters for the other variables function as expected for detecting drowsiness.	Type	Test
Tester Information			
Name of Tester	Victor Bellera Tovar, Theodor Owchariw	Date	4.11.24
Hardware/Software Ver.	Position2Go, MATLAB	Time	1:00 PM

Setup		Sitting in car with mirror mounted on windshield slightly above head of tester, with mirror angled slightly downward. Laptop will be open with MATLAB to confirm testing results. Run program, wait 10 seconds for initialization then begin testing procedures.				
Step	Actions	Expected Results	P a s s	F a i l	N / A	Comments
1	Head: Up Respiration: Low Time: Short	Falling Asleep	Y	N		
2	Head: Up Respiration: Low Time: Medium	Falling Asleep	Y	N		

3	Head: Up Respiration: Low Time: Long	Falling Asleep	Y	N		
4	Head: Up Respiration: Normal Time: Short	Awake	Y	N		
5	Head: Up Respiration: Normal Time: Medium	Awake	Y	N		
6	Head: Up Respiration: Normal Time: Long	Falling Asleep	Y	N		
7	Head: Up Respiration: High Time: Short	Awake	Y	N		
8	Head: Up Respiration: High Time: Medium	Awake	Y	N		

9	Head: Up Respiration: High Time: Long	Awake	Y	N		
10	Head: Down Respiration: Low Time: Short	Falling Asleep	N	Y		Took 2 extra runs to become true
11	Head: Down Respiration: Low Time: Medium	Asleep	N	Y		Slight changes in setup may have caused error
12	Head: Down Respiration: Low Time: Long	Asleep	Y	N		
13	Head: Down Respiration: Medium Time: Short	Falling Asleep	N	Y		Took 2 tries for success
14	Head: Down Respiration: Medium Time: Medium	Falling Asleep	Y	N		
15	Head: Down Respiration: Medium Time: Long	Asleep	Y	N		

16	Head: Down Respiration: High Time: Short	Awake	Y	N		
17	Head: Down Respiration: High Time: Medium	Falling Asleep	Y	N		1 False positive
18	Head: Down Respiration: High Time: Long	Falling Asleep	Y	N		
Overall Test Result						Accuracy: 15/18

Table 13: Testing and Validation Sheet 2

Discussion

Throughout the project we were informed of our sponsor's desire for a completely autonomous system that's able to detect drowsiness using a mmWave radar. This presented us with a multitude of ways to approach the problem. As we have demonstrated in our previous documents, we decided to implement the following drowsiness indicators: breathing rate, head position, time of day, and driving time. In the results using the aforementioned indicators, we were able to achieve 88.88% and 83.33% accuracy for the first and second test respectively. Most of the failures in our testing were due to bad initializations of the head position and not issues with the algorithm itself. We found that the majority of the time, it took an extra run of the while loop to update the status of drowsiness; however, the bad initializations led to even more runs being needed. At the time of performing the testing, the breathing rate was not implemented; therefore, the breathing state was hardcoded. After acquiring breathing rate, it is possible that we actually achieve a lower accuracy score due to issues with frequency isolation of breathing rate. Luckily, we were able to confirm the algorithm works well and that the head position isolation is accurate.

Conclusion

Reflecting on our senior design project to develop a drowsiness detection rear view mirror, the team gained significant insights and valuable experiences. The process of designing Bayesian network code and creating physical prototypes with 3D software underscored the importance of detailed planning and technical precision. Managing our time effectively and delegating tasks efficiently were crucial in meeting our milestones. Additionally, immersing ourselves in signal processing was critical for effectively implementing our detection algorithms. Collaborative problem-solving and thorough troubleshooting of radar issues were invaluable experiences that not only enhanced our practical engineering skills but also prepared us for future challenges. This project not only met its objectives but also laid a strong foundation for future advancements in this vital area of automotive safety technology.

Future Work

In a future implementation of this project, we aim to refine the sensitivity of our respiration algorithm to capture more nuanced variations in breathing patterns. This enhancement will allow for more precise assessments of a driver's alertness, contributing significantly to the prevention of accidents related to fatigue. Additionally, we plan to integrate heart rate monitoring into our system. By analyzing multiple physiological indicators, including heart rate fluctuations, our device will offer a more comprehensive and accurate detection of drowsiness. Implementing this feature presents challenges, particularly in accurately measuring subtle changes such as heartbeat. Lastly, our team would like to further refine the Bayesian network. This could include adding more parameters, and altering how the Bayesian network makes its decisions. However, overcoming these challenges will greatly advance the functionality of our system, making it an essential tool for ensuring driver safety. These improvements were beyond the scope of the current project due to time constraints. However, they represent critical next steps in our pursuit to develop a more sophisticated and reliable drowsiness detection technology.

References

- [1] P. -L. Cheng and C. -L. Yang, "Heart Rate Detection With Hilbert Vibration Decomposition in Random Body Movements Based on FMCW Radars," in *IEEE Microwave and Wireless Technology Letters*, vol. 33, no. 6, pp. 935-938, June 2023, doi: 10.1109/LMWT.2023.3268347.
- [2] Ahmed S, Abdullah M, Alouini M. mm-Wave Radar-Based Multiple Patients' Breathing and Heart Rates Measurement. *Research Square*; 2023. DOI: 10.21203/rs.3.rs-2966459/v1.
- [3] C. Ding et al., "Inattentive Driving Behavior Detection Based on Portable FMCW Radar," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 67, no. 10, pp. 4031-4041, Oct. 2019, doi: 10.1109/TMTT.2019.2934413.
- [4] C. Will, P. Vaishnav, A. Chakraborty and A. Santra, "Human Target Detection, Tracking, and Classification Using 24-GHz FMCW Radar," in *IEEE Sensors Journal*, vol. 19, no. 17, pp. 7283-7299, 1 Sept.1, 2019, doi: 10.1109/JSEN.2019.2914365.
- [5] H.-I. Choi, W.-J. Song, H. Song, and H.-C. Shin, "Selecting Target Range with Accurate Vital Sign Using Spatial Phase Coherency of FMCW Radar," *Applied Sciences*, vol. 11, no. 10, p. 4514, May 2021, doi: <https://doi.org/10.3390/app11104514>.
- [6] K. Qu, L. Wei, and R. Zhang, "Noncontact Cardiac Activity Detection Based on Single-Channel ISM Band FMCW Radar," *Biosensors*, vol. 13, no. 11, p. 982, Nov. 2023, doi: <https://doi.org/10.3390/bios13110982>.

Appendix

Codes and Standards

Project Codes:

- The device shall affect the Vehicle's overall power consumption by an insignificant margin.
 - The Position2Go radar is a power-efficient board that consumes very little power.
 - The built-in MCU has a low-power mode which allows the board to go on standby when applicable.
- The device shall function without the need for manual user input and work passively.
 - The software is designed to be standalone and will run all necessary processes automatically.
- Housing for the microcontroller and radar shall fit most average-sized vehicles without hindering the driver's overall visibility.
 - The Position2Go radar is compact and will easily fit in a standard-sized vehicle.
- The system shall notify the user once the device determines that drowsiness has been detected.
 - For the scope of this project, hardware indicators will not be used but simulated indicators via MATLAB will be.
- The project shall be created with a reasonable cost of materials to develop the device.
 - Position2Go is relatively affordable and the chassis is 3D printed using affordable filament.
- The device shall use a microprocessor for its drowsiness detection algorithm.
 - The Position2Go radar has a built-in microprocessor that works directly with the radar.
- The device shall be powered through an external power source.

- The Position2Go radar is powered via a 5v micro USB port.
- The device shall contain a radar to propagate waves for biometric detection.
 - The POSITION2GO radar is compact and can easily fit inside of a rear-view mirror.
- The device shall comply with the Federal Motor Vehicle Safety Standard (FMVSS)
- The device shall operate in the proper frequencies and power requirements

Ethic Codes:

Team members are required to be familiar with the NSPE Engineering Code of Ethics as they are responsible for their obligations to the public, the client, the employer, and the profession. There will be stringent following of the NSPE Engineering Code of Ethics.

Safety Standards:

3D Printing: The housing was printed a day before pickup to eliminate the risk of burns from hot filament. Rough edges were sanded down to prevent cuts and abrasions.

Programming: Programming was done in intermittent sessions, with intermediate discussions allowing for breaks in typing and brainstorming. Programming was also done with proper posture and in an environment that would not cause any eye strain.

Testing: Caution was used when being in proximity to the radar. This included only necessary and limited exposure. It also included keeping the radar at a safe distance at all times.

Code of Conduct

Mission Statement

Our team is committed to ensuring a positive work environment that supports professionalism, integrity, respect, and trust. Every member of this team will contribute a full effort to the creation and maintenance of such an environment in order to bring out the best in all of us as well as this project.

Roles

Each team member is delegated a specific role based on their experience and skill sets and is responsible for all here-within:

(Disclosure: These responsibilities are allocated to specific members; however, the roles are malleable and other members can facilitate each other)

Team Leader – Theodor Owchariw

Manages the team as a whole; develops a plan and timeline for the project, delegates tasks among group members according to their skill sets; finalizes all documents and provides input on other positions where needed. The team leader is responsible for promoting synergy and increased teamwork. If a problem arises, the team leader will act in the best interest of the project.

He keeps the communication flowing, both between team members and Sponsor. The team leader takes the lead in organizing, planning, and setting up meetings. In addition, he is responsible for keeping a record of all correspondence between the group and ‘minutes’ for the meetings. Finally he gives or facilitates presentations by individual team members and is responsible for overall project plans and progress

Team members:

Financial Advising - All Members

Manages the budget and maintains a record of all credits and debits to the project account. Any product or expenditure requests must be presented to the advisor, whom is then responsible for reviewing and the analysis of equivalent/alternate solutions. They then relay the information to the team and if the request is granted, order the selection. A record of these analyses and budget adjustments must be kept. The majority of the hardware is provided so this will be done by the majority of the group and not be allocated towards a singular person.

Hardware development - Luke Forbis, Ben Covitz, Victor Bellera Tovar

Manages all the physical elements of the rearview mirror. This includes the casing, wiring, and other various adjustments that will be revealed as the project progresses. Research the hardware elements of the project and coordinate with the software team.

Software development - Lucas Torres, Theodor Owchariw

Develops the algorithm to process the radar information and predict if the driver is drowsy. Develop any other software necessary for the project.

All Team Members:

- Work on certain tasks of the project
- Buys into the project goals and success
- Delivers on commitments
- Adopt team spirit
- Listen and contribute constructively (feedback)
- Be effective in trying to get message across
- Be open minded to others ideas
- Respect others roles and ideas
- Be ambassador to the outside world in own tasks

Communication

The main form of communication to address the entire group will be over email. For addressing team members one-on-one, texting and phone calls may be permitted in addition to emails. Texting the whole group may be permitted for urgent/impromptu events. Other forms of communication will be over phone and text-messaging among the group, preferably phone as well as through regular meetings of the whole team. Email will be a secondary form of communication for issues not being time-sensitive. For the passing of information, i.e. files and presentations, email will be the main form of file transfer and proliferation.

Each group member must have a working email for the purposes of communication and file transference. Members must check their emails at least twice a day to check for important information and updates from the group.

Although members will be initially informed via an email/phone message, meeting dates and pertinent information from the sponsor will additionally be sent over email so it is very important that each group member checks their email frequently.

If a meeting must be canceled, an email must be sent to the group at least 24 hours in advance.

Any team member that cannot attend a meeting must give advance notice of 24 hours informing the group of his absence. Reason for absence will be appreciated but not required if personal. Repeated absences in violation with this agreement will not be tolerated.

Email Guidelines to TEAM ONLY

- email subject start with “ SENIOR DESIGN TEAM:” “info regarding to email”
- email must cc: all team members

Team Dynamics

The students will work as a team while allowing one another to feel free to make any suggestions or constructive criticisms without fear of being ridiculed and/or embarrassed. If any member on this team finds a task to be too difficult it is expected that the member should ask for help from the other teammates. If any member of the team feels they are not being respected or taken seriously, that member must bring it to the attention of the team in order for the issue to be resolved. We shall NOT let emotions dictate our actions. Everything done is for the benefit of the project and together everyone achieves more.

Ethics

Team members are required to be familiar with the NSPE Engineering Code of ethics as they are responsible for their obligations to the public, the client, the employer, and the profession. There will be stringent following of the NSPE Engineering Code of Ethics.

Dress Code

Team meetings will be held in casual attire. Sponsor meetings and group presentations will be business casual to formal as decided by the team per the event. For meetings that are decided to be in anything more than casual attire an email or way of notification will be sent out at least 1 day before.

Weekly and biweekly Tasks

Team members will participate in the majority of meetings when with the sponsor, adviser and or instructor. Exceptions will apply to team members with previous notice “of one day or less for emergencies/unforeseen circumstances that arise” to the team that they are unable to make it or if certain members are notified that it is not necessary for them to attend. During said times ideas, project progress, budget, conflicts, timelines and due dates will be discussed. In addition, tasks will be delegated to team members during these meetings. Repeat absences will not be tolerated.

Inability to meet a deadline will be assessed at each meeting. If a team member is unable to meet a deadline, all team members must be notified prior to the due date. The amount of time prior is malleable and dependent on the difficulty of the task. This will also be discussed and assigned at each meeting.

When assigning a task, the following will be included:

- When the task should be completed by
- Who is assigned to the task
- Status-check date (Dependent on project difficulty)
- Task description
- Deliverables

Decision Making

It is conducted by consensus and majority of the team members. Should ethical/moral reasons be cited for dissenting reasons, then the ethics/morals shall be evaluated as a group and the majority will decide on the plan of action. Individuals with conflicts of interest should not participate in decision-making processes but do not need to announce said conflict. It is up to each individual to act ethically and for the interests of the group and the goals of the project. Achieving the goal of the project will be the top priority for each group member. Below are the steps to be followed for each decision-making process:

- Problem Definition – Define the problem and understand it. Discuss among the group.
- Tentative Solutions – Brainstorms possible solutions. Discuss among group most plausible.
- Data/History Gathering and Analyses – Gather necessary data required for implementing Tentative Solution. Re-evaluate Tentative Solution for plausibility and effectiveness.
- Design – Design the Tentative Solution product and construct it. Re-evaluate for plausibility and effectiveness.
- Test and Simulation/Observation – Test design for Tentative Solution and gather data. Re-evaluate for plausibility and effectiveness.
- Final Evaluation – Evaluate the testing phase and determine its level of success. Decide if design can be improved and if time/budget allows for it.

Conflict Resolution

In the event of discord amongst team members the following steps shall be respectfully employed:

- Communication of points of interest from both parties which may include demonstration of active listening by both parties through paraphrasing or other tools acknowledging clear understanding.
- Administration of a vote, if needed, favoring majority rule.
- Team Leader intervention.
- Instructor will facilitate the resolution of conflicts.

Code of ethics is amenable if and only if all team members have a 100% agreement on an amendment and each must sign each new amendment document.

Statement of Understanding

By signing this document the members of Team 312 agree to all of the above and will abide by the code of conduct set forth by the group.

Name	Signature	Date
<u>Theodor Owchariw</u>	<i>Theodor Owchariw</i>	<u>9/27/23</u>
<u>Lucas Torres</u>	<i>Lucas Torres</i>	<u>9/27/23</u>
<u>Luke Forbis</u>	<i>Luke Forbis</i>	<u>9/27/23</u>
<u>Ben Covitz</u>	<i>BCovitz</i>	<u>9/27/23</u>
<u>Victor Bellera</u>	<i>Victor Bellera</i>	<u>9/27/23</u>

Other Engineering Figures and Tables

1st Functional Decomposition

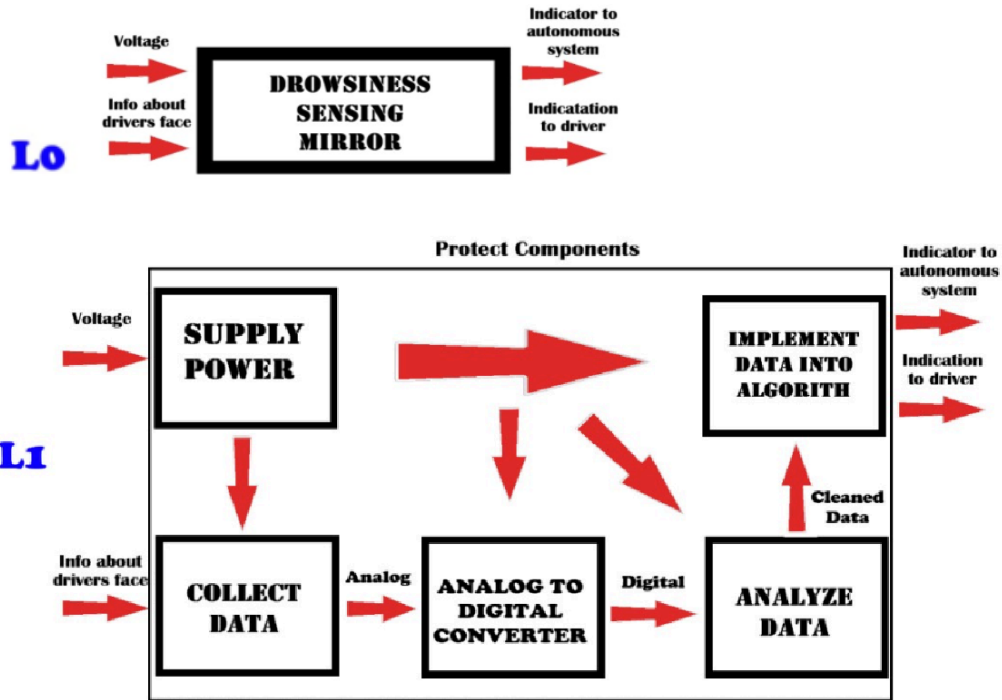


Figure 6: Original Functional Decomposition

2nd Functional Decomposition

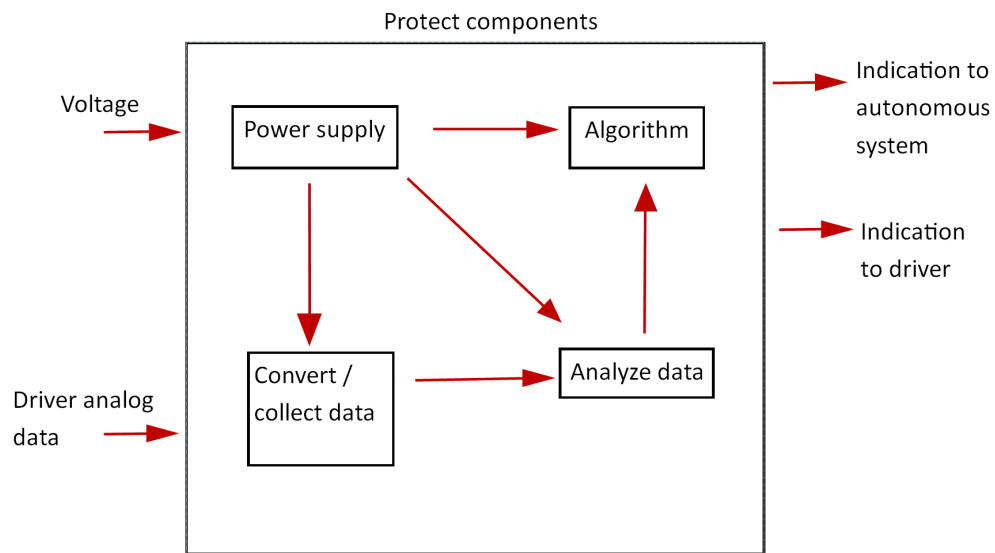


Figure 7: Revised Functional Decomposition

Original Component Breakdown

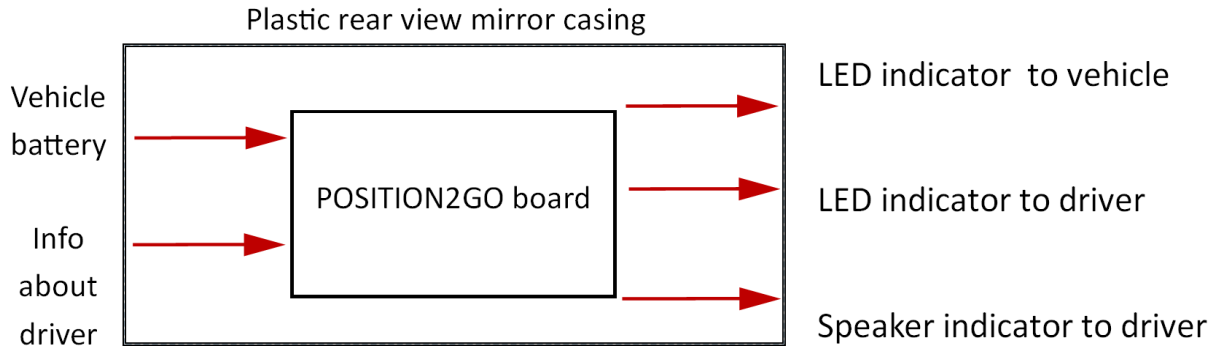


Figure 8: Original Component Breakdown

Target Catalog

No.	Function/Need	Target	Metric
1	Collect Data	Range: 500 - 2000 mm	Distance from driver to sensor (mm)
2	Rear View Mirror Size	28.5 x 7 x 2.5 cm^3	Volume (cm^3)
3	Supply Power	5 V	Voltage (V)
5	Analyze Data	Yes	Binary (Y/N)
6	Running Algorithm	>30%	Percent accuracy of drowsiness detection
7	Indication to driver	Yes	Binary (Y/N)
8	Indication to vehicle	Yes	Binary (Y/N)
9	Output is not distracting	Yes	Binary (Y/N)
10	Power consumption	< 1 W	Watts consumed

Table 14: Target Catalog

Engineering drawings

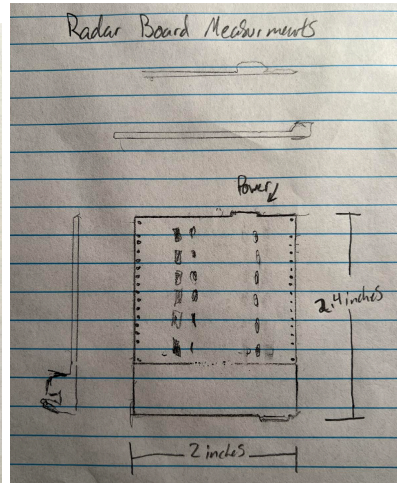
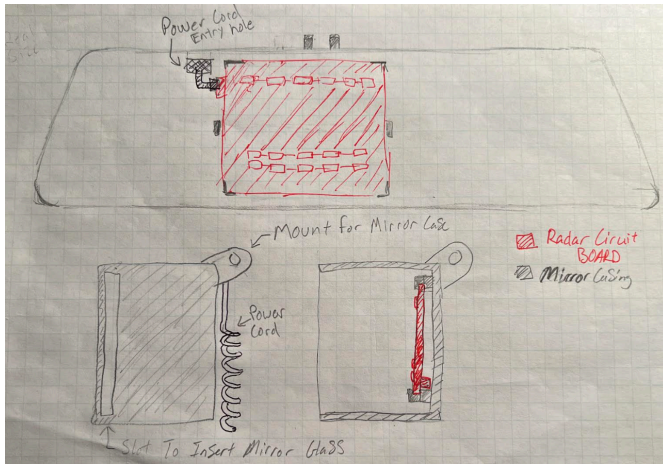
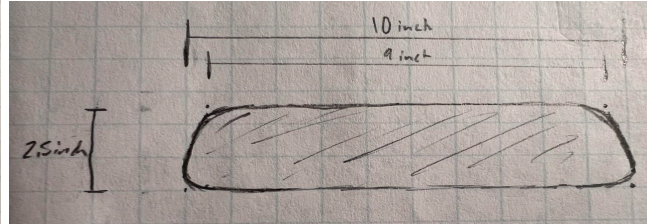
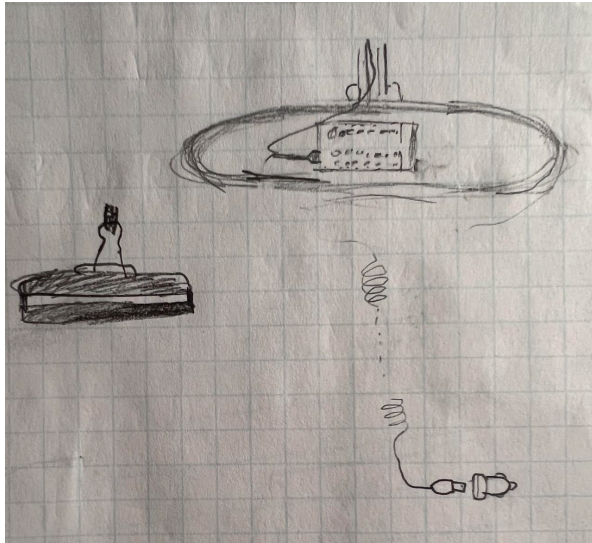


Figure 9: Mirror Housing Sketches

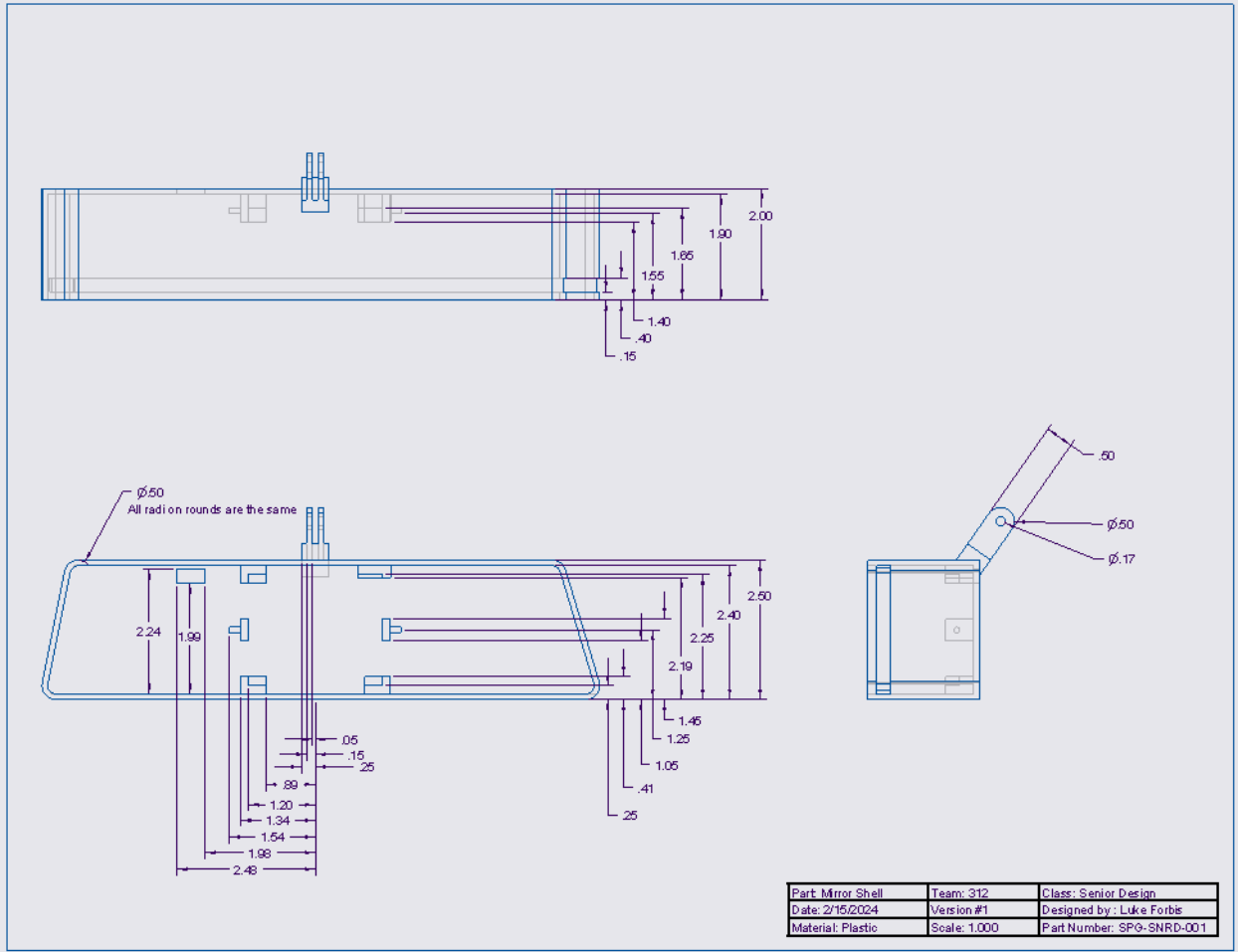


Figure 10: Mirror Housing Schematic

Project Hazard Assessment Policy and Procedures

INTRODUCTION

University laboratories are not without safety hazards. Those circumstances or conditions that might go wrong must be predicted and reasonable control methods must be determined to prevent incident and injury. The FAMU-FSU College of Engineering is committed to achieving and maintaining safety in all levels of work activities.

PROJECT HAZARD ASSESSMENT POLICY

Principal investigator (PI)/instructor are responsible and accountable for safety in the research and teaching laboratory. Prior to starting an experiment, laboratory workers must conduct a project hazard assessment (PHA) to identify health, environmental and property hazards and the proper control methods to eliminate, reduce or control those hazards. PI/instructor must review, approve, and sign the written PHA and provide the identified hazard control measures. PI/instructor continually monitor projects to ensure proper controls and safety measures are available, implemented, and followed. PI/instructor are required to reevaluate a project anytime there is a change in scope or scale of a project and at least annually after the initial review.

PROJECT HAZARD ASSESSMENT PROCEDURES

It is FAMU-FSU College of Engineering policy to implement followings:

1. Laboratory workers (i.e. graduate students, undergraduate students, postdoctoral, volunteers, etc.) performing a research in FAMU-FSU College of Engineering are required to conduct PHA prior to commencement of an experiment or any project change in order to identify existing or potential hazards and to determine proper measures to control those hazards.
2. PI/instructor must review, approve and sign the written PHA.
3. PI/instructor must ensure all the control methods identified in PHA are available and implemented in the laboratory.
4. In the event laboratory personnel are not following the safety precautions, PI/instructor must take firm actions (e.g. stop the work, set a meeting to discuss potential hazards and consequences, ask personnel to review the safety rules, etc.) to clarify the safety expectations.
5. PI/instructor must document all the incidents/accidents happened in the laboratory along with the PHA document to ensure that PHA is reviewed/modified to prevent reoccurrence. In the event of PHA modification a revision number should be given to the PHA, so project members know the latest PHA revision they should follow.
6. PI/instructor must ensure that those findings in PHA are communicated with other students working in the same laboratory (affected users).
7. PI/instructor must ensure that approved methods and precautions are being followed by :
 - a. Performing periodic laboratory visits to prevent the development of unsafe practice.
 - b. Quick reviewing of the safety rules and precautions in the laboratory members meetings.
 - c. Assigning a safety representative to assist in implementing the expectations.
 - d. Etc.

8. A copy of this PHA must be kept in a binder inside the laboratory or PI/instructor's office (if experiment steps are confidential).

Project Hazard Assessment Worksheet				
PI/instructor: Dr. Jerris Hooker	Phone #:(850) 410-6463	Dept.: ECE	Start Date: January 2024	Revision number:
Project: Drowsiness Sensing Rear View Mirror			Location(s): College of Engineering, ECE Senior Design Lab	
Team member(s): Lucas Torres, Luke Forbis, Ben Covitz, Victor Bellera Tovar, Theodor Owchariw			Team Lead Phone #: 954-279-0785	Team Lead Email: to20@fsu.edu

Experiment Steps	Location	Person assigned	Identify hazards or potential failure points	Control method	PPE	List proper method of hazardous waste disposal, if any.	Residual Risk	Specific rules based on the residual risk
Soldering electrical components to board	COE A314	Ben Covitz, Luke Forbis, Victor Bellar Tovar	Soldering, solder fumes	Fan on the table	Eye protection	Dispose of solder on brass wool	HAZARD : hot soldering iron, toxic fumes CONSEQ: burn self, lung damage Residual: Medium	Buddy system when soldering first aid kit
3D printing	Innovation Hub/Remote	Luke Forbis	Sharp edges, plastic dust, sanding	Use sandpaper opposed to palm sander	Gloves, eye protection, mask	Carefully remove sharp edges and dispose of material residues/dust	HAZARD : sharp edges, plastic dust, sanding CONSEQ: cuts, lung damage, abrasion injuries Residual: Low	Buddy system First aid kit should be accessible at all times Wait an hour after printing to touch the object

Programming	COE, Remote location (home)	Lucas Torres, Theodor Owchar iw	sitting and typing for long periods	Take rests every hour and stretch	N/A	N/A	HAZARD : sitting and typing for long periods of time CONSEQ: poor posture, carpal tunnel	Progra mmers should take hourly breaks to avoid specifie d hazards .
							Residual: Low	
Assembling	COE A314	All Member s	Minor electrocution	Handle component s after grounding	Ground ing	N/A	HAZARD : electrocuti on CONSEQ: slight discomfort	All membe rs should be ground ed during assembl y
							Residual: Low-Med	
Testing	COE, stationary car	All Member s	EM radiation from radar to eyes, head, and chest	Keep radar at safe operating distance from body Reduce time of exposure to experiment s only	N/A	N/A	HAZARD : Radiation CONSEQ: eyesight deteriorati on	Keep a safe distanc e from the radar Do not stare directly at radar
							Residual: Low Med	

Table 15: Project Risk Hazard Assessment Tracker

Principal investigator(s)/ instructor PHA: I have reviewed and approved the PHA worksheet.

Name	Signature	Date	Name	Signature	Date
_____	_____	_____	_____	_____	_____

Team members: I certify that I have reviewed the PHA worksheet, am aware of the hazards, and will ensure the control measures are followed.

Name	Signature	Date
<u>Theodor Owchariw</u>	<i>Theodor Owchariw</i>	<u>12/1/23</u>
<u>Lucas Torres</u>	<i>Lucas Torres</i>	<u>12/1/23</u>
<u>Luke Forbis</u>	<i>Luke Forbis</i>	<u>12/1/23</u>
<u>Ben Covitz</u>	<i>BCovitz</i>	<u>12/1/23</u>
<u>Victor Bellera</u>	<i>Victor Bellera</i>	<u>12/1/23</u>

DEFINITIONS:

Hazard: Any situation, object, or behavior that exists, or that can potentially cause ill health, injury, loss or property damage e.g. electricity, chemicals, biohazard materials, sharp objects, noise, wet floor, etc. OSHA defines hazards as “*any source of potential damage, harm or adverse health effects on something or someone*”. A list of hazard types and examples are provided in appendix A.

Hazard control: Hazard control refers to workplace measures to eliminate/minimize adverse health effects, injury, loss, and property damage. Hazard control practices are often categorized into following three groups (priority as listed):

- 1. Engineering control:** physical modifications to a process, equipment, or installation of a barrier into a system to minimize worker exposure to a hazard. Examples are ventilation (fume hood, biological safety cabinet), containment (glove box, sealed containers, barriers), substitution/elimination (consider less hazardous alternative materials), process controls (safety valves, gauges, temperature sensor, regulators, alarms, monitors, electrical grounding and bonding), etc.
- 2. Administrative control:** changes in work procedures to reduce exposure and mitigate hazards. Examples are reducing scale of process (micro-scale experiments), reducing time of personal exposure to process, providing training on proper techniques, writing safety policies, supervision, requesting experts to perform the task, etc.

3. **Personal protective equipment (PPE):** equipment worn to minimize exposure to hazards. Examples are gloves, safety glasses, goggles, steel toe shoes, earplugs or muffs, hard hats, respirators, vests, full body suits, laboratory coats, etc.

Team member(s): Everyone who works on the project (i.e. grads, undergrads, postdocs, etc.). The primary contact must be listed first and provide phone number and email for contact.

Safety representative: Each laboratory is encouraged to have a safety representative, preferably a graduate student, in order to facilitate the implementation of the safety expectations in the laboratory. Duties include (but are not limited to):

- Act as a point of contact between the laboratory members and the college safety committee members.
- Ensure laboratory members are following the safety rules.
- Conduct periodic safety inspection of the laboratory.
- Schedule laboratory clean up dates with the laboratory members.
- Request for hazardous waste pick up.

Residual risk: Residual Risk Assessment Matrix are used to determine project’s risk level. The hazard assessment matrix (table 1) and the residual risk assessment matrix (table17) are used to identify the residual risk category.

The instructions to use hazard assessment matrix (table 16) are listed below:

1. Define the workers familiarity level to perform the task and the complexity of the task.
2. Find the value associated with familiarity/complexity (1 – 5) and enter value next to: HAZARD on the PHA worksheet.

		Complexity		
		Simple	Moderate	Difficult
Familiarity Level	Very Familiar	1	2	3
	Somewhat Familiar	2	3	4
	Unfamiliar	3	4	5

Table 16: Hazard Assessment Matrix

The instructions to use residual risk assessment matrix (table 2) are listed below:

1. Identify the row associated with the familiarity/complexity value (1 – 5).
2. Identify the consequences and enter value next to: CONSEQ on the PHA worksheet. Consequences are determined by defining what would happen in a worst case scenario if controls fail.
 - a. Negligible: minor injury resulting in basic first aid treatment that can be provided on site.
 - b. Minor: minor injury resulting in advanced first aid treatment administered by a physician.
 - c. Moderate: injuries that require treatment above first aid but do not require hospitalization.
 - d. Significant: severe injuries requiring hospitalization.
 - e. Severe: death or permanent disability.
3. Find the residual risk value associated with assessed hazard/consequences: Low –Low Med – Med– Med High – High.

4. Enter value next to: RESIDUAL on the PHA worksheet.

Assessed Hazard Level	Consequences				
	Negligible	Minor	Moderate	Significant	Severe
5	Low Med	Medium	Med High	High	High
4	Low	Low Med	Medium	Med High	High
3	Low	Low Med	Medium	Med High	Med High
2	Low	Low Med	Low Med	Medium	Medium
1	Low	Low	Low Med	Low Med	Medium

Table 17: Residual Risk Assessment Matrix

Specific rules for each category of the residual risk:

Low:

- Safety controls are planned by both the worker and supervisor.
- Proceed with supervisor authorization.

Low Med:

- Safety controls are planned by both the worker and supervisor.
- A second worker must be in place before work can proceed (buddy system).
- Proceed with supervisor authorization.

Med:

- After approval by the PI, a copy must be sent to the Safety Committee.
- A written Project Hazard Control is required and must be approved by the PI before proceeding. A copy must be sent to the Safety Committee.
- A second worker must be in place before work can proceed (buddy system).
- Limit the number of authorized workers in the hazard area.

Med High:

- After approval by the PI, the Safety Committee and/or EHS must review and approve the completed PHA.
- A written Project Hazard Control is required and must be approved by the PI and the Safety Committee before proceeding.
- Two qualified workers must be in place before work can proceed.
- Limit the number of authorized workers in the hazard area.

High:

- The activity will not be performed. The activity must be redesigned to fall in a lower hazard category.
-

Types of Hazard	Example
Physical hazards	Wet floors, loose electrical cables objects protruding in walkways or doorways
Ergonomic hazards	Lifting heavy objects Stretching the body Twisting the body Poor desk seating
Psychological hazards	Heights, loud sounds, tunnels, bright lights
Environmental hazards	Room temperature, ventilation contaminated air, photocopiers, some office plants acids

Hazardous substances	Alkalis solvents
Biological hazards	Hepatitis B, new strain influenza
Radiation hazards	Electric welding flashes Sunburn
Chemical hazards	Effects on central nervous system, lungs, digestive system, circulatory system, skin, reproductive system. Short term (acute) effects such as burns, rashes, irritation, feeling unwell, coma and death. Long term (chronic) effects such as mutagenic (affects cell structure), carcinogenic (cancer), teratogenic (reproductive effect), dermatitis of the skin, and occupational asthma and lung damage.
Noise	High levels of industrial noise will cause irritation in the short term, and industrial deafness in the long term.
Temperature	Personal comfort is best between temperatures of 16°C and 30°C, better between 21°C and 26°C. Working outside these temperature ranges: may lead to becoming chilled, even hypothermia (deep body cooling) in the colder temperatures, and may lead to dehydration, cramps, heat exhaustion, and hyperthermia (heat stroke) in the warmer temperatures.
Being struck by	This hazard could be a projectile, moving object or material. The health effect could be lacerations, bruising, breaks, eye injuries, and possibly death.
Crushed by	A typical example of this hazard is tractor rollover. Death is usually the result
Entangled by	Becoming entangled in machinery. Effects could be crushing, lacerations, bruising, breaks amputation and death.
High energy sources	Explosions, high pressure gases, liquids and dusts, fires, electricity and sources such as lasers can all have serious effects on the body, even death.
Vibration	Vibration can affect the human body in the hand arm with 'white-finger' or Raynaud's Syndrome, and the whole body with motion sickness, giddiness, damage to bones and audits, blood pressure and nervous system problems.
Slips, trips and falls	A very common workplace hazard from tripping on floors, falling off structures or down stairs, and slipping on spills.
Radiation	Radiation can have serious health effects. Skin cancer, other cancers, sterility, birth deformities, blood changes, skin burns and eye damage are examples.
Physical	Excessive effort, poor posture and repetition can all lead to muscular pain, tendon damage and deterioration to bones and related structures
Psychological	Stress, anxiety, tiredness, poor concentration, headaches, back pain and heart disease can be the health effects
Biological	More common in the health, food and agricultural industries. Effects such as infectious disease, rashes and allergic response.

Table 18: Hazard Types and Examples

Operation Manual

Project Overview:

The drowsiness-sensing rear-view mirror aims to reduce motor vehicle accidents attributed to drowsy driving. The rear-view mirror uses a radar system to record the driver's biometrics and determine if they are drowsy according to various factors.

Component/Module Description:

Position2Go Board:

The Position2Go board uses an FMCW radar system to record the distance between itself and a target. It also has a microprocessor to perform the signal processing needed to extract biometrics from the driver and run the decision-making algorithm to determine drowsiness. The board is currently discontinued so there is a limited supply of these boards available and tech support does not make this board a high priority.

Caution: Radiation from the board could potentially cause harm if held too close to a person's eyes or body in general when it is on.

Mirror Housing:

The housing is a 3D printed, slightly modified, variant of a standard rear-view mirror. The length and height are very similar; however, the width is deeper to account for any other physical hardware to be added in other iterations as well as working as a physical filter which facilitates filtering of noise. The housing contains a slot to hold the Position2Go in place as well as a slot to run its micro USB cable through so that it does not interfere with anything inside.

Data Extraction:

The board transmits a wave at 24 GHz out into the world and receives the reflected wave from objects in its way. The board then finds the difference between the transmitted and received radar signals on its own and outputs this into MATLAB. The raw data is then processed with techniques such as windowing and filtering to reduce unwanted noise. Then, the displacement of the chest and head can be found within the data by looking at the plotted frequency domain. These variables and their respective state is then fed into the algorithm.

Algorithm:

The algorithm used to predict drowsiness is a Bayesian Network. This network uses Bayes Theorem to calculate the probability of a dependent event occurring given the knowledge of various independent event outcomes. The dependent event is drowsiness. The independent events are the driving time, head position, breathing rate, and time of day. The biometric events are initially determined during the data extraction process and are constantly polled to check their updated status and assign a new state. The numerical values for the driving time, head position, and breathing rate are one-hot encoded, meaning we assign a specific state dependent on the value we get after processing the radar data. A posterior probability calculation is performed to obtain the probability of drowsiness based on the given evidence. We then use this probability to encode three different drowsiness states: awake, falling asleep, and asleep. The decided state is then assigned to a specific LED color and unique alert indicator sound.

Integration:

MATLAB is used to interface with the Position2Go board to process the raw data received from the driver. The incoming data is preprocessed to eliminate noise and filter out higher-frequency data. Next, frequency isolation is performed to extract the driver's head position (and breathing rate). The head position and breathing rate are monitored over time to observe any changes that the decision-making algorithm may attribute to drowsiness. In addition to these factors, the decision-making algorithm gathers evidence of the other relevant events to determine drowsiness. Lastly, the Position2Go board is placed inside the mirror housing so that it is secure during a typical drive and has a clear view of the driver.

Operation:

There is only one mode of operation for the device. To use the drowsiness-sensing rear view mirror, first place the mirror to the interior of a car windshield near where the existing rear view mirror is. This should be a safe distance for the driver to not be affected by the radar radiation. Once securely fastened to the interior of the windshield, connect the device to a personal laptop using the micro USB connector. Next, select the desired "test conditions" for this drive in MATLAB by setting the current drive time. Finally, run the MATLAB script to analyze the biometrics of the driver and determine their drowsiness in real-time.

Troubleshooting:

(1) Broken mirror housing: Due to average wear and tear of setting up the 3D printed chassis in the vehicle, there were issues with portions of the housing chipping or breaking. To resolve this, modify and download the stl file. Then send it to the FSU Innovation Hub for free 3D printing.

(2) MATLAB issues: There were two issues that impacted our device's functionality. The first issue was the radar data pulling in MATLAB. There was built-in Infineon code that would send an error and break out of the loop if there was a bad byte when pulling data. This, luckily, was

resolved by allowing it to rerun more than once to pull functional data. We decided on 10 reruns. The second issue was that after a few updates of the virtual LED plot, the MATLAB program would pause indefinitely. To resolve this, simply close the plot and it will re-open the updated plot and continue running the algorithm. We are looking into a permanent fix for this error. If either of the issues persists, terminate the program, unplug the board from the computer, and rerun it until the issue goes away.

(3) If drowsiness detection is very inaccurate, make sure that the mirror is properly aimed at the driver. Consider changing the location or angle at which the radar is in view of the driver. The board is very sensitive to changes in location so make sure not to be moving the mirror around once initialization begins. During the initialization process, the driver should be very still to ensure that the radar is getting the proper location of its environment. Failure to do so may result in the board not getting proper initial readings resulting in all future comparisons being inaccurate.