Mar 17, 2019

Craig Scratchley

School of Engineering Science

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Re: ENSC 405W/440 Design Specification for FoCoS (Forward **Co**llision Warning **S**ystem**) by TRAFEC**

Dear Dr. Scratchley,

The following document contains an overview of the functional specifications of our project for ENSC 405/440: FoCoS. The goal of this project is to make an aftermarket front collision warning system for cars. The system will be designed to alert the driver in case of upcoming collision to prevent or reduce the severity of the crash. FoCoS will be of big advantage in high traffic area or when driver is unconscious which is the reason for most of the front collisions. Due to its object tracking technology, in addition to detecting collisions it can also be used for other applications like detecting pedestrians or other objects that can cause a crash.

This document will provide our design we have for both our electronic components and software system. An explanation will be provided on how each requirement specified in Requirements document will be implemented. Then we will go in depth explaining the technology and sensors involved and how they are going to integrate with each other to turn into final product. Product design requirements will be laid down in this document for FoCoS alongside their stage of completion i.e. Proof of Concept, Prototype and Production and with level of priority each requirement holds.

Our team consists of 4 individuals who are passionate about finding solutions to traffic problem bringing safer and faster commute to people. Our team has Avneet Kaur, Abhishek Mahajan, Ranbir Makkar (CCO) and Amitoj Singh. If you have any questions or comments, please direct them to rmakkar@sfu.ca.

Sincerely,

Ranbir Makkar

Chief Communications Officer

DESIGN SPECIFICATIONS

FoCoS (Forward Collision warning System)

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Abstract

Forward Collision Warning (FCW) systems are quite common in modern cars. In March 2016, the National Highway Traffic Safety Administration (NHTSA) and the Insurance Institute for Highway Safety announced that manufacturers of U.S. automobiles agreed to include automatic emergency braking systems based on Forward Collision Warning as standard on virtually all new cars coming in the U.S. by 2022. In 2012, Europe had a similar agreement about advanced emergency braking system (AEBS) or autonomous emergency braking (AEB) [1]. Any FCW equipped vehicle is less prone to an accident and makes you and others feel safer on the roads but there are still many old cars running on the roads. They don't have such technology in their cars.

The FoCoS by TRAFEC is reliable, affordable, and trustable aftermarket solution for the cars that are not provided with such technology. This document provides the preliminary design specifications for each of the FoCoS' components. The goal of this document is to provide detailed understanding of the design choices our team has made.

FoCoS is made of 5 main components: the micro-controller to calculate the closing time and do the image processing, the radar sensor to detect the frontal object's distance and speed, the camera to capture the frontal object, the speaker for the audio alert to the driver, and the head-up display for the visual alert.

The design specifications can be separated into software and hardware functionalities. TRAFEC is determined to the fact that their team will be able to tackle the requirements laid out in this document and intend to follow the relevant engineering standards.

Glossary

Closing time Time required for the collision to occur based on the relative speed of 2 objects and the distance between them

Frontal object Any object in front of the car is considered as Frontal object. It could be any vehicle, pedestrian or other stationary body

Subject Vehicle Vehicle equipped with FoCoS

Audio Alert 1 600Hz sound at a rate of 1 beep/sec

Audio Alert 2 600Hz sound at a rate of 2 beep/sec

User Driver of the subject vehicle

Old Car Car not equipped with newer safety technology like Front Collision Warning systems

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1 Introduction

1.1 Background

A forward collision warning system (FCW) is an automobile safety system designed to reduce the severity of an accident. FCW uses radar and camera to detect an imminent crash. An on-board sensor detects the frontal object and the system determines whether there is a risk of collision. After the detection has been made these systems warns the driver about the crash using audio and visual warnings. Below are some of the common situations where FCW can be helpful:

- Car in front of you has stopped at green light due to an obstacle in front of it and you're travelling too fast towards it
- You are looking at your infotainment system and the car ahead accidently pressed brakes
- The vehicle ahead suddenly slows down to turn without giving signal
- You do not notice the car in front pressed brakes due to bad weather and/or low visibility

All the problem listed above have the potentials to put drivers at the risk of collision. The National Highway Traffic Safety Administration estimates that 16% of fatalities and 20% of the injuries in the U.S. involved driver distraction [2]. Also, the statistics from ICBC revealed that in 2013, 29% of the fatal accidents were caused by distracted driving [3].

FoCoS is completely based on the idea of FCW but this product will be an aftermarket option for the older cars to experience the new technology. FoCoS will come with an inbuilt speaker but can also be integrated to car's sound system (may be an external speaker depending on the car) to provide audio warnings and a head's up display will provide the visual warning.

1.2 Scope

The following document is meant to fully rely on the functional requirements document for FoCoS. The document will provide the detailed overview of the design specifications for each of the components that FoCoS is composed of. All the relevant engineering standards that we will comply to and high-level design will be presented.

1.3 Classification

To organize and describe the design requirements, the following format will be used:

[DES<Section Number>.<Subsection>-<Priority>-<Type>]

Example: REQ.2.1.2-H-PoC

DES stands for requirements. **Section Number** refers to the numerical value assigned to each section and **Subsection** points to the number value assigned to the subsection of the Section. **Priority** and **Type** are described in the table below.

Priority	Description
H	High Priority

M	Medium Priority
L	Low Priority

TABLE 1-1: PRIORITY ENCODING DESCRIPTION

Development Stage	Description
PoC	Proof of Concept
P	Prototype
F	Production Ready

TABLE 1-2: DEVELOPMENT STAGE DESCRIPTION

2 System Overview

The aim of the FoCoS is to bring the forward collision warning system into the old cars and the new cars that are not equipped with this technology.

FoCoS is a compact device which consists 3 main units:

Detection Unit- 1 radar sensor and 1 camera
Processing unit- 1 microcontroller
Alert Unit- 1 head-up display and 1 audio output.

The detection unit will be connected to the front of the car to sense the frontal object (car or pedestrian) incase it's too close to the vehicle. A warning will be sent out to the driver using the head-up display and subject car's audio system.

The detection unit will have the radar sensor as its primary sensor and a camera as its secondary sensor. Speed of travel and distance from other vehicles will be determined by monitoring changes in the Doppler Shift of the radio wave after it bounces off something and returns to the point where it started. In addition, the camera will continuously monitor changes in distance of the Subject Vehicle from various objects on the road. Based on this data a closing time will be calculated and if that closing time is less than certain threshold a warning will be sent out to the driver. If the driver presses the brake in the span of 3 seconds after the warning has been sent out, the car should stop without colliding with the object. Fig 2-1 show the high level description of the product.

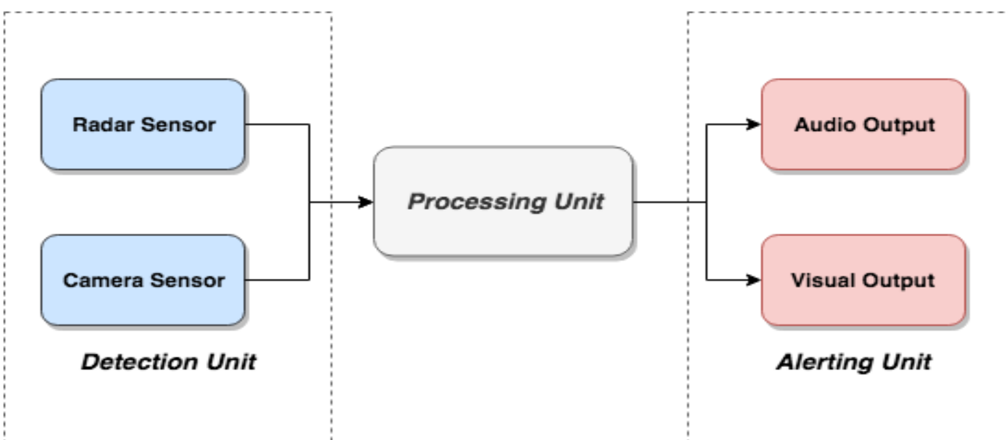

FIGURE 2-1: BLOCK DIAGRAM OF FOCOS

Fig 2-2 gives the final look of the product. The speaker shown here will be integrated in the main unit with a speaker mesh around it, it has been shown this way to give better look of placement of the things.

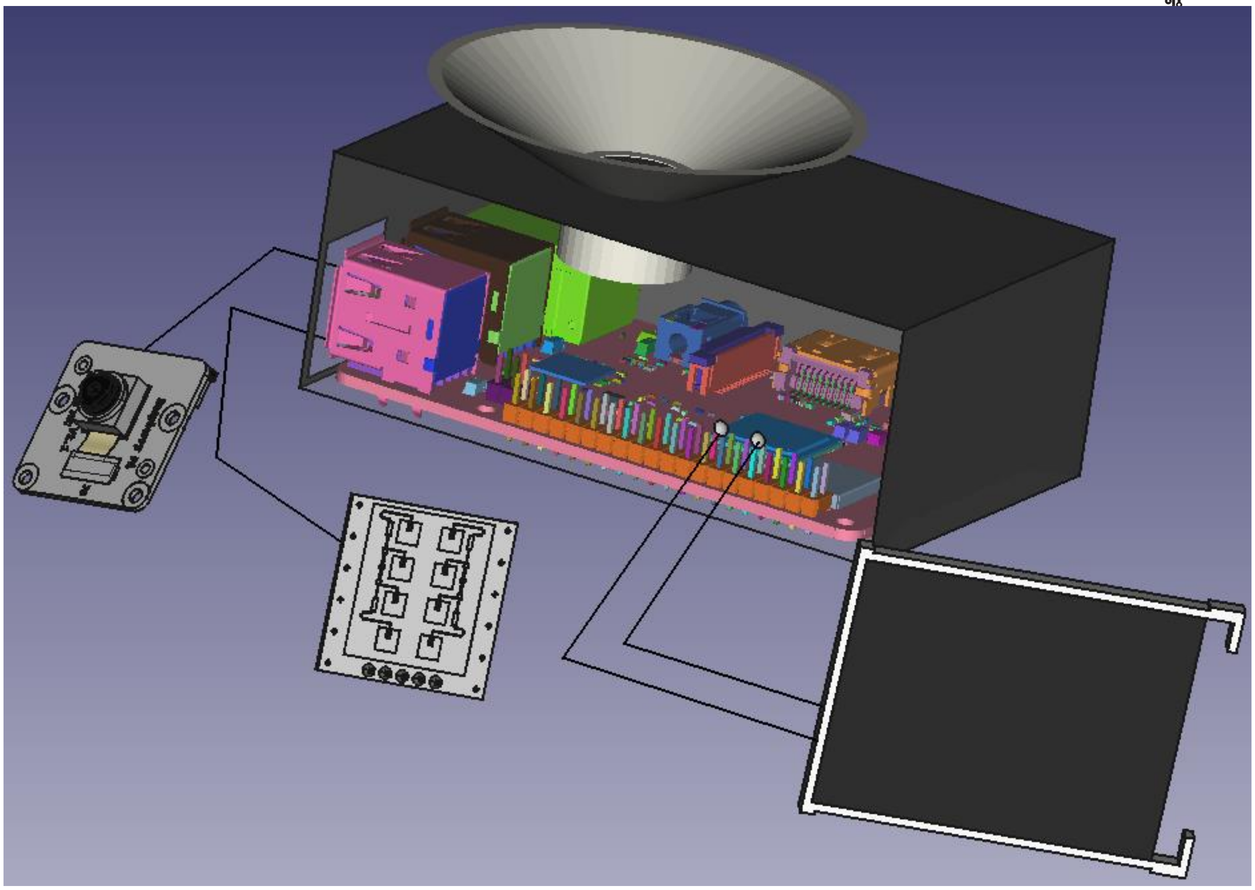

FIGURE 2-2: FOCOS' FINAL LOOK

Fig 2-3 gives the conceptual view of how the FoCoS will work.

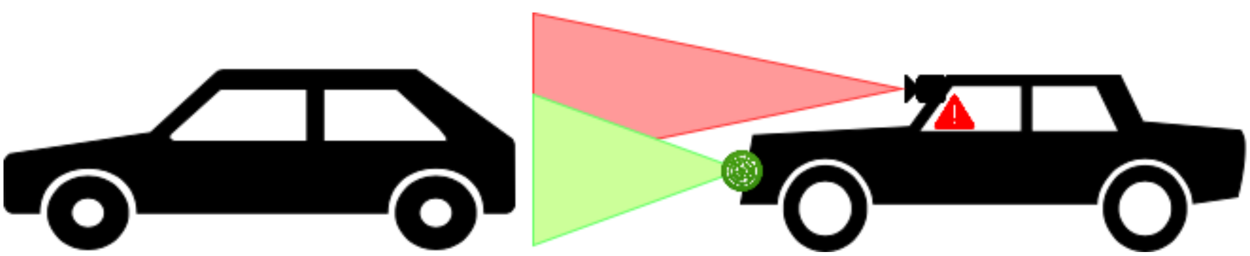

FIGURE 2-3: CONCEPTUAL DIAGRAM VISUALIZING THE FOCOS

3 Electrical Design

3.1 Main Computer

The following table includes the design specifications for the system.

Design ID	Design Specification
DES 3.1.1-H-P	The system is able to run complex image processing software
DES 3.1.2-M-F	Includes a camera module interface
DES 3.1.3-H-F	Includes enough GPIO pins for visual and audio feedback
DES 3.1.4-H-P	Should be able to fit in the Sensor enclosure

TABLE 3-1: MAIN COMPUTER DESIGN SPECIFICATIONS

The main processing unit for FoCoS is a Raspberry Pi B+. It boasts a 64-bit quad core processor running at 1.4 GHz, dual-band 2.4GHz and 5 GHz wireless LAN, Bluetooth 4.2/BLE, with a faster Ethernet, and PoE capability via a separate PoE HAT. It has a 1GB SDRAM memory. Since the release of Raspberry Pi, it has been an ideal choice for most projects that involve some kind of prototyping due to its effective design and affordable price. This Raspberry Pi operates at 5 V/2.5 A DC via micro USB connector or 5 V DC via GPIO header, that is perfect for creating a prototype. This development board has a MIPI CSI camera port as well as a MIPI DSI displays port. The camera port will be used to process the real-time video information sent by the camera and the display port will be used to give visual feedback. The 40-pin GPIO header on the board will be used accordingly in order to give audio feedback to the user. Fig 3-1 give a detailed view of Raspberry pi.

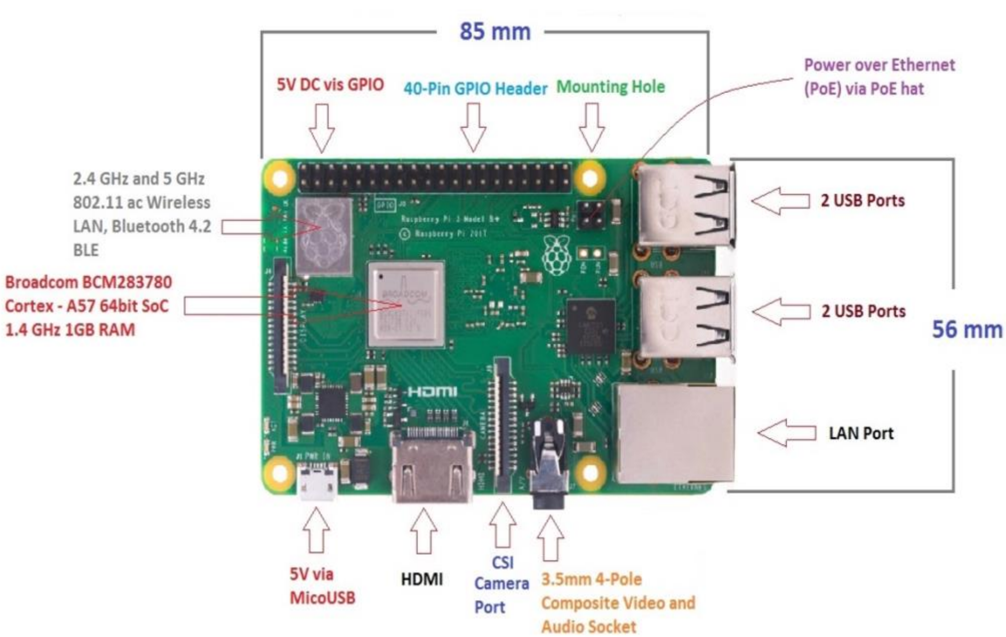

FIGURE 3-1 RASPBERRY PI 3 MODEL B+ [25]

3.2 Camera Module

The following table includes the design specifications for the camera module.

Design ID	Design Specification
DES 3.2.1-H-P	The camera module will interface with Raspberry Pi 3 Model B+
DES 3.2.2-H-P	The camera module will have a 5MP resolution
DES 3.2.3-H-P	The camera module will have a fixed focal length

TABLE 3-2: CAMERA MODULE DESIGN SPECIFICATIONS

The camera selected for the design is Keyestudio Camera Module 5MP REV 1.3 compatible with Raspberry Pi 3 Model B+. The camera has a native resolution of 5MP and has a fixed focal length. The camera is capable of 2595X1944 static images. The image sensor board is 25mmX24mmX9mm and weighs just over 3g. The camera will be connected to the Raspberry Pi using a ribbon cable in the prototype. Fig 3-2 is the picture of camera used in FoCoS.

FIGURE 3-2 RASPBERRY PI CAMERA MODULE [4]

3.3 Power Supply

The following table includes the design specifications for the power supply.

Design ID	Design Specification
DES 3.3.1-H-P	Product won’t drain power, if the vehicle is off
DES 3.3.2-H-P	Raspberry Pi will consume at least 3000 mA of current

TABLE 3-3: POWER SUPPLY DESIGN SPECIFICATIONS

The main power source for the device is the power outlet in the vehicle. The power outlet supplies 12 V DC which should be more than enough for the device to operate [5]. The device will have an on/Off switch as well and will only consume power depending on the positioning of this switch.

3.4 Audio Feedback

The following table includes the design specifications for the audio feedback.

Design ID	Design Specification
DES 3.4.1-H-P	Output audio feedback signal to user
DES 3.4.2-H-P	Output sound should be of frequency 600hz
DES 3.4.3-H-F	Output sound should have beeps that should increase by 1,2,3 beeps/sec based on the level of danger
DES 3.4.4-M-P	Output sound shall only be given when you are less than the 4.5 sec to closing time

TABLE 3-4: AUDIO OUTPUT DESIGN SPECIFICATIONS

Raspberry pi does have an aux output for audio, but the power provide by aux is not enough to output loud enough sound from the speaker. For our purpose we are using "**Mini External USB 2.0 Speaker**" which uses USB to plug in. The picture of the speaker is shown below in Fig 3-3.

FIGURE 3-3 MINI EXTERNAL USB 2.0 SPEAKER

4 Mechanical Design

The mechanical design of FoCoS needs to be planned thoroughly. Since some part of our device is going to be on the front bumper of the car, we want the internal components of the device to be protected against the environment, chip stones or bugs hitting the car. Along with that, we also want to make sure that our device is comfortable and easy to use for the user's.

4.1 Environmental Considerations

Since the device is going to be exposed to the outdoor environment, it should be able to withstand high and low temperatures and modest amounts of dust and moisture as well. We want users around the world to be able to use our device under different environmental conditions without any concern that the device might not be able to withstand such conditions and might malfunction or cause damage.

The following table includes the plastic codes with pros and cons.

Plastic Code	Pros	Cons
ABS	High temperature resistance (-20^0 C to 105^0 C), strong, flexible [6]	Difficult to 3D print, oil based, emits toxic printing fumes [7]
PETG	Moderate temperature resistance (-20^0 C to 80^0 C), strong, chemical and water resistant, recyclable [8] [9]	Difficult to 3D print, more expensive than the other two alternatives
PLA	Easy to 3D print, biodegradable [10]	Low temperature and moisture resistant (upto 55^0 C), brittle [10] [11]

TABLE 4-1: PLASTIC CODES WITH PROS AND CONS

After looking at the above mentioned options of some of the most common and inexpensive 3D printable plastics, along with their design constraints, PETG would be the best choice for the outer coverage of our sensors that go on the front bumper of the vehicle as well as for the raspberry pi which is going to be inside the car in the cabin. We chose PETG since, it has the necessary strength in all reasonable temperature ranges. It is also water and chemical resistance, which makes our product even more robust. The portion where we have the radar is going to be covered with acrylic so that the sensor can works properly.

Camera module will also be placed in an enclosure. In addition to having necessary strength and temperature tolerance, the camera enclosure will be attached to the windshield using provided adhesive tapes.

The following table includes the design specifications for the environmental considerations.

Design ID	Design Specification
DES 4.1.1-H-P	Sensor enclosure will not warp in hot weather conditions and nor will it become brittle in cold weather conditions
DES 4.1.2-M-F	Dust will not be able to collect on internal components and will not interfere with the proper functioning of our product
DES 4.1.3-H-F	Humid environment will not hinder in the functioning of our product

TABLE 4-2: ENVIRONMENTAL CONSIDERATIONS DESIGN SPECIFICATIONS

4.2 User Considerations

We are trying to make FoCoS as user friendly as possible which is why we are planning to make it easy for the user to install and make it more like a plug and play device. The sensors are going to have an adhesive on them so that they can be attached to the front bumper easily. The sensors will be connected with a wire that runs through the hood into the cabin and connect to the raspberry pi. The raspberry pi is going to have an adhesive on it as well which the user can use to attached to where they feel it will comfortable inside the cabin.

The camera will also have an adhesive on it, which will be used for easy installation of the camera on the windshield. In addition, the camera will be connected with a cable to the raspberry pi. The cable will be long enough such that the camera can reach the top of windshield when the raspberry pi is place in the glove compartment of the car. In addition, the cable will be attachable to the sides of the windshield using provided adhesive so that the cable does not block the view of the driver or annoys the driver by hanging in a moving vehicle.

There is going to be one power switch on the raspberry pi with a led. This button is going to be designed such that the user should get proper feedback from it when they interact with it. The power switch will have a tactile and audible click to indicate the user that the state of the switch has changed. The switch will have proper labelling to indicate which state is On and which state is Off.

The following table includes the design specifications for the user considerations.

Design ID	Design Specification
DES 4.2.1-M-F	The power switch is going to have a tactile and auditory click
DES 4.2.2-M-F	Adhesive will be strong enough to hold the sensors and raspberry pi in place

TABLE 4-3 USER CONSIDERATIONS DESIGN SPECIFICATIONS

5 Software Design

A high level software design can be seen in the figure 5-1. The software design of FoCoS will consist of 4 major components. The first software component will be responsible for getting input from the Radar sensor. The second software component will be responsible for getting input from the Camera and performing object detection using those inputs. The third software component will be responsible for sending alerts as needed by driving the Audio and Visual output. The fourth software component will be responsible for calculating closing time based on data received from the first and second components, sending the calculated closing time to the third component as well as maintaining a state machine for FoCoS. For the prototype, the system software will be designed for Dense Traffic Mode only.

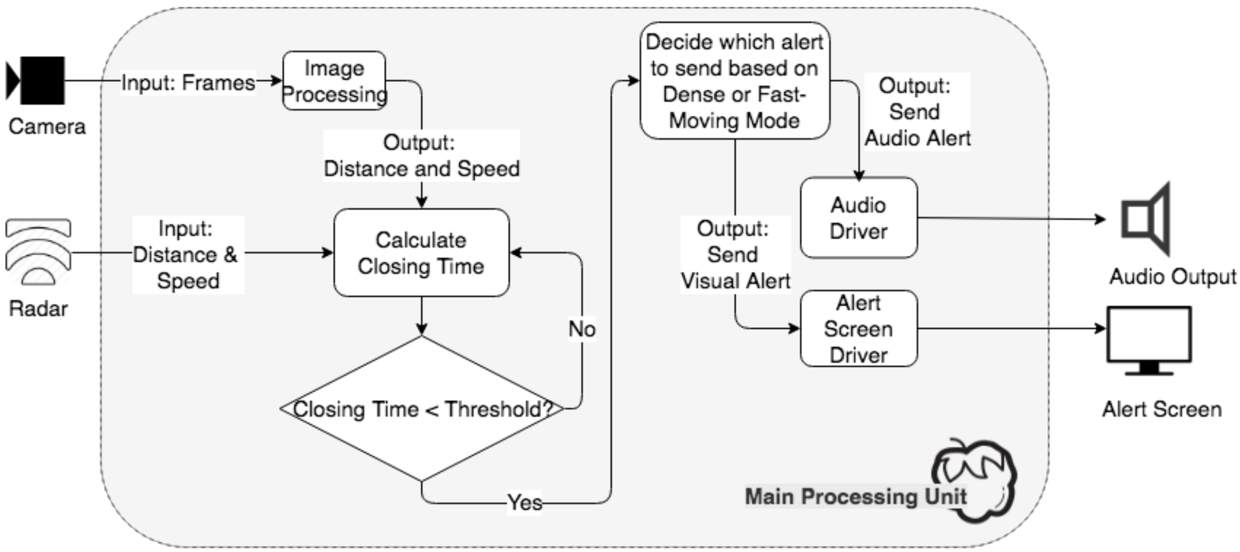

FIGURE 5-1 HIGH LEVEL SOFTWARE OVERVIEW [12]

5.1 General

The main tasks of the software are to calculate closing time, set the next state of system based on current state and closing time, and based on state, signal the Feedback software component to send out alerts.

The following table includes the design specifications for the general software.

Design ID	Design Specification
DES 5.1.1-H-P	The system software will accept input from radar and camera software components every 0.1 seconds
DES 5.1.2-H-P	The system software will calculate closing time every time it gets a new input
DES 5.1.3-H-F	The system software will maintain next device state depending on current state and input

DES 5.1.4-M-P	On startup, the system software will be in IDLE state
DES 5.1.5-M-P	When the system is in IDLE state and calculated closing time is less than threshold closing time or system is in Dense Moving Traffic mode, system software will change state to WARNING
DES 5.1.6-H-P	When the system is in WARNING state and closing time is less than 4.5 seconds, system software will change next state to STOP
DES 5.1.7-M-F	When system is in WARNING or STOP state and closing time is greater than 4.5 seconds, system software will change next state to IDLE

TABLE 5-1 GENERAL SOFTWARE DESIGN SPECIFICATIONS

The following figure 5-2 shows the state diagram at a glance.

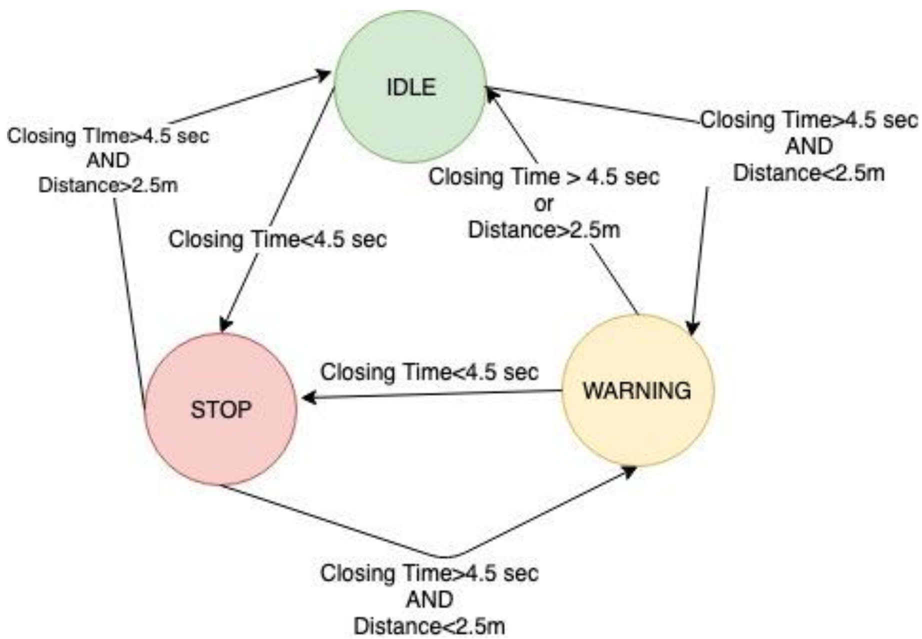

FIGURE 5-2 SOFTWARE STATE DIAGRAM

5.2 Radar Input Gathering

The system software will read radar sensor's output by using raspberry pi's GPIOzero library. GPIOZero provides a simple interface to GPIO devices with Raspberry Pi.

Following table includes the design specifications for radar input gathering:

Design ID	Design Specification
DES 5.2.1-H-P	On startup, system software will start reading radar output every 0.1 seconds
DES 5.2.2-M-P	System software will send radar output as distance/speed to main software

	component

TABLE 5-2 RADAR INPUT GATHERING SOFTWARE DESIGN SPECIFICATIONS

5.3 Image Processing with Object Detection

Object Detection refers to the process of finding object instances such as cars, humans, poles, signs in still images or videos [13] This can be seen in the following figure 5-3. It allows for recognition, localization and detection of multiple objects within an image, which will provide an advanced field of view for the system [13] . It will be used to detect obstacles and provide timely feedback to the driver, which is the main purpose of FoCoS.

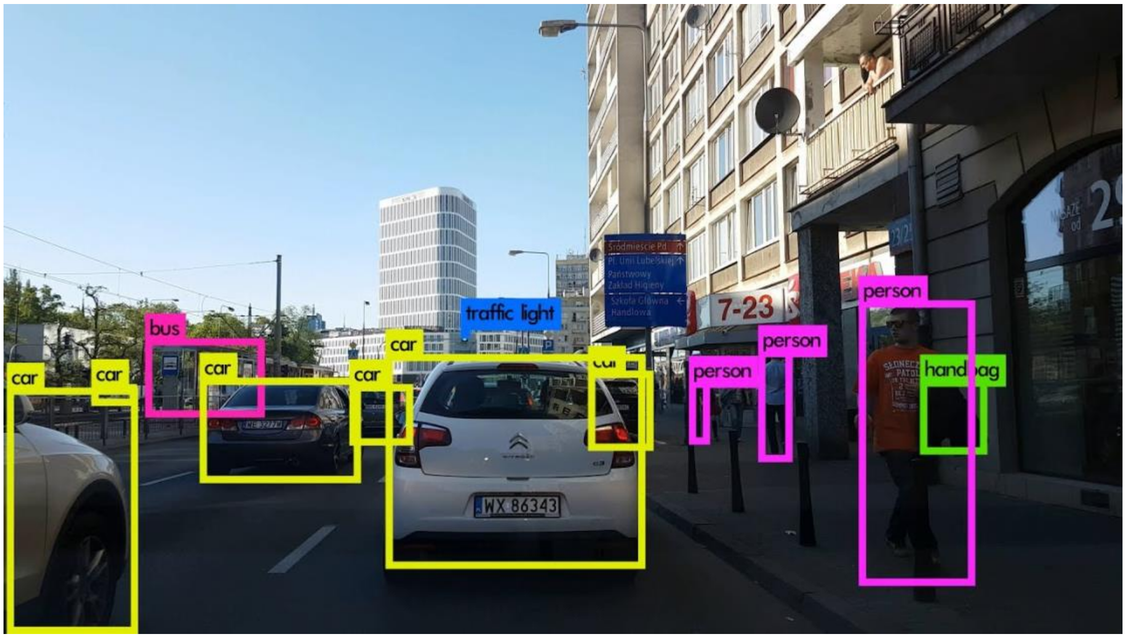

FIGURE 5-3 SAMPLE OBJECT DETECTION [14]

The system software will use TensorFlow Object Detection API [15], which is Google's open source machine learning framework for dataflow programming across a range of tasks. The system software will use a model pre-trained on the COCO dataset, which is lightweight and contains 90 common objects including cars, pedestrians and other objects found on road.

Following table includes the design specifications for image processing:

Design ID	Design Specification
DES 5.3.1-H-P	The system software will accept frames from camera at the rate of 30 frames per second (fps)
DES 5.3.2-H-P	The system software will use TensorFlow with a pre-trained model to quickly detect and identify objects
DES 5.3.3-L-F	The system software will calculate distance/speed of obstacle using OpenCV

DES 5.3.4-H-P	The system software will send all calculated data to main software component

Table 5-3 Image Processing Software Design Specifications

5.4 Feedback

This software component will consist of drivers for Audio Output and Alert Screen. Feedback software component will be updated whenever there is a change in state (no alert ->visual alert (warning) , visual alert -> audio alert (stop), audio alert -> no alert, visual alert -> no alert)

Following table includes the design specifications for the feedback software:

Design ID	Design Specification
DES 5.4.1-H-P	The system software will accept data from main software component giving next state of system
DES 5.4.2-M-F	On startup, Audio Output and Alert Screen will be OFF
DES 5.4.3-H-F	If Audio Output and Alert Screen are OFF and input state is IDLE, Audio Output and Alert Screen will remain OFF
DES 5.4.4-M-P	If Audio Output and Alert Screen are OFF and input state is WARNING, Alert Screen will be turned ON and Audio Output will remain OFF
DES 5.4.5-M-P	If Alert Screen is ON, Audio Output is OFF and input state is STOP, Audio Output will be turned ON to give Audio Alert 1
DES 5.4.6-M-F	If Alert Screen is ON and input state is IDLE, Alert Screen will be turned OFF
DES 5.4.7-M-F	If Audio Output is ON and input state is IDLE or WARNING, Audio Output will be turned OFF

Table 5-4 Feedback Software Design Specifications

6 Conclusion

The FoCoS is a small and intelligent device that will help you in getting out more safely on the roads. By having a sensor and camera always looking for an obstacle, FoCoS will add an extra layer of security in your car. Not only the car equipped with FoCoS is safe but the cars and pedestrians around that car are also safe. The best part about the FoCoS is that it is an inexpensive device which makes it available to everyone in the need of such device.

FoCoS is comprised of 3 main subsystems:

Detection unit:

a) Detection is being made by the 25 m range RADAR sensor and the camera
b) Both RADAR and the camera sends their data to the processing unit
c) RADAR is reliable in all weather conditions and works perfectly during the nights too
d) Camera will help the device for the better identification of the object

Processing unit:

Processing unit is a single board computer which is responsible for following tasks:

a) Input: Gather the input data from RADAR and the camera for closing time and image processing respectively
b) Output: Once the processing is done, it sends the desired output to the alerting unit

Alerting unit:

Alerting unit is composed of one speaker and an LCD screen

a) Speaker is responsible for the audio alerts which are triggered by the processing unit
b) Same way LCD is also triggered by the processing unit to provide the visual waring to the driver

TRAFEC will consider the design specification as a reference document for the prototype as the team proceeds developing it in the coming months. Our team hopes that this business model combined with our design approach will result into a reliable and truly useful product.

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8 Appendix A: Test Plan

8.1 Introduction

This appendix document provides a detailed test plan for FoCoS and its subsystems as well.

8.2 Usability Testing

The following tests will be performed on the user's interaction with the device. The tests will cover all the device's functionality and subsystems.

Date:	**Test Name:** Power cycling
Test Description: Turn the vehicle off, switch the power button on and off, take out the power cable from the power outlet and plug it back in	
Expected Outcome: The device should be off it the vehicle is off, or the power switch is off otherwise it should be on	
Actual Outcome:	

Date:	**Test Name:** Error detection for radar
Test Description: Place a moving object in front of the radar	
Expected Outcome: The radar should be able to give accurate readings by giving right distance and speed of object	
Actual Outcome:	

Date:	**Test Name:** Error detection for camera
Test Description: Face the camera towards different objects that could be present on the road	
Expected Outcome: The camera should be able to detect and distinguish the objects in front of it correctly	
Actual Outcome:	

8.3 Electronics Testing

The following tests will be performed on the electronic components of FoCoS.

Date:	**Test Name:** Audio signal quality
Test Description: Perform a test on the audio signal for the frequency sweep	
Expected Outcome: All the frequencies outside the range of audio band (20Hz-20kHz) should be diminished	
Actual Outcome:	

Date:	**Test Name:** Visual feedback display
Test Description: Perform a test on the brightness of the display	
Expected Outcome: The display should be bright enough to be seen in all weather conditions	
Actual Outcome:	

Date:	**Test Name:** Current draw measurements
Test Description: Measure the current draw of the different components (camera, LED, microcomputer, RADAR) of the system and the system as a whole	
Expected Outcome: The total current drawn by the whole system should not be more than 1A	
Actual Outcome:	

Date:	**Test Name:** Power efficiency
Test Description: Check if the Processing unit (Raspberry Pi) powers off when the engine is not running	
Expected Outcome: Processing unit should power OFF when the car is turned off and it should also turn off all other components (camera, LED, speaker and, RADAR sensor) since they're all getting power from the processing unit	
Actual Outcome:	

8.4 Mechanical Testing

The following tests will be performed on the mechanical components of FoCoS. These tests may be performed on the device as a whole system or on some specific mechanical component of the device. Following are the table for mechanical testing:

Date:	**Test Name:** Drop test
Test Description: Drop the various components of the system on the different surfaces from about 1 meter and check for any damage	
Expected Outcome: The system components should not get any significant damage	
Actual Outcome:	

Date:	**Test Name:** Dust test
Test Description: Expose the RADAR sensor (rest of the components will be inside the car) to the dust for about 4 hours and check for any bad effect on performance of the sensor	
Expected Outcome: The dust should not do any damage to the sensor, since the sensor would we covered with the transparent material to protect it from the dust	
Actual Outcome:	

Date:	**Test Name:** Weather testing
Test Description: Expose the RADAR sensor to all weather conditions to check for any malfunctions in the working of sensor	
Expected Outcome: Different weather conditions should not do any damage to the sensor, since the sensor would we covered with the transparent material to efficiently work in all weather conditions	
Actual Outcome:	

Date:	**Test Name:** Camera test
Test Description: Perform a test on the placement of the camera to be able to see objects clearly for identification	
Expected Outcome: The camera should be able to have a clear vision and no movement is required after it has been installed	
Actual Outcome:	

Date:	**Test Name:** Sensor Temperature testing
Test Description: Leave the sensor in different temperature settings using refrigerator and heaters ranging from (-40°C to 40°C) and perform a test on any issue with the working of the sensor	
Expected Outcome: The sensor should work perfectly fine with no effect from the different temperature settings	
Actual Outcome:	

8.5 Software Testing

Following are the tables for software testing:

Date:	**Test Name:** Radar Input Test
Test Description: Place a moving object in front of the radar and print output of radar detected speed	
Expected Outcome: Printed speed should be same as speed of moving object	
Actual Outcome:	

Date:	**Test Name:** Camera Object Detection Test
Test Description: Place a car, a human and a pole in front of the camera and print out text description of object detected by the camera	
Expected Outcome: Printed text description should match the description of object in the correct order	
Actual Outcome:	

Date:	**Test Name:** Camera Object Distance Detection Test
Test Description: Place an object at a distance of 100m, 50m, 25m and 5 m and print out distance detected by image processing software	
Expected Outcome: Printed distance should match the actual distance and should be in the correct order	
Actual Outcome:	

Date:	**Test Name:** Closing Time Calculation Test
Test Description: Place a moving object in front of radar and camera with closing time of 5 seconds, 4.5 seconds, 3 seconds and print out closing time	
Expected Outcome: Printed closing time should match the actual closing time	
Actual Outcome:	

Date:	**Test Name:** State Change Test
Test Description: Turn on Device, place a moving object with closing time>4.5 second and distance<2.5m, then place a moving object with closing time<4.5 seconds, then remove object from field of view. Print state of device at each change.	
Expected Outcome: Printed state should be IDLE, then WARNING, then STOP and then IDLE again	
Actual Outcome:	

Date:	**Test Name:** Alert Screen Feedback Test
Test Description: Place a moving object with closing time >4.5 second and distance<2.5m in front of device, then remove object from field of view. Print output that goes from feedback software component to Alert Screen Driver	
Expected Outcome: Printed output should go from OFF to ON and ON to OFF	
Actual Outcome:	

Date:	**Test Name:** Audio Output Feedback Test
Test Description: Place a moving object with closing time <4.5 second in front of device, then remove the object. Print output that goes from feedback software component to Audio Output Driver	
Expected Outcome: Printed output should go from OFF to ON and then ON to OFF	
Actual Outcome:	

Date:	**Test Name:** Idle State Test
Test Description: Turn on device. Print device state.	

Expected Outcome: Printed state should be IDLE
Actual Outcome:

9 Appendix B: User Interface

9.1 Introduction

The Appendix will give a detailed overview of User Interface of FoCoS. We will explain the design choices for the user interfaces, analyze how our users will use the product, and discuss design considerations based on Don Norman's "Seven elements of UI Interaction" - namely discoverability, feedback, conceptual models, affordances, signifiers, constraints.

Users of the FoCoS will people who drives an old car and want to add extra feature to make his or her car safer. Being an aftermarket product, we not just want it to be cheaper, but we also want to make it easy to install and use. We are trying to target easy installation, so user doesn't need to involve mechanic in this process, all he has to do is plug and play. To achieve so we need to follow some usability design principles and make our product similar common electronics. This way we can bring familiar experience and consistency to our product.

9.1.1 Purpose

The purpose of this appendix is to explain the design of FoCoS's user interaction and provide an overview of the UI's main components and their functionality.

9.1.2 Scope

This appendix will focus on the product's user interface. It contains an analysis on our users and how they will interact with our device

9.2 User Analysis

As mentioned before FoCoS user can be anyone with a car and want to add an extra safety feature. This helps us narrow down our user to adults (person with a driving licence at least). At the core we have a microcontroller which will behave like a normal computer or a mobile phone. Our users will likely have experience with using these devices, and be familiar with its user interface, including the way a smartphone powers on and off with a long push on the power button, plugin in to power using car 12V power outlet and installing small system in car. If our user interface differs too much from these common household smart devices, our users may find the device foreign and be deterred from using it.

We will, however, keep to the expected conventions for our LED lights, which will use green for ok, yellow for standby, and red for error. Since these LED lights are not very bright, they won't become a distraction.

9.3 Technical Analysis

This section will analyze FoCoS's user interface based on Don Norman's Seven elements of UI Interaction, which includes the following design factors: discoverability, feedback, conceptual models, affordances, signifiers, mappings, and constraints.

9.3.1 Discoverability

Discoverability explains how easily a user can locate various user interface elements when they are interacting the product for the first time, and discover what they can do with buttons, switches, and other elements of the product. FoCoS's UI is designed with minimalism in mind, providing a clean interface with the essentials only, such as the power button, LED displays to indicate the status and any errors that occur and a power input. These buttons are placed on the device based on common device designs, which will make them intuitive to find for the user.

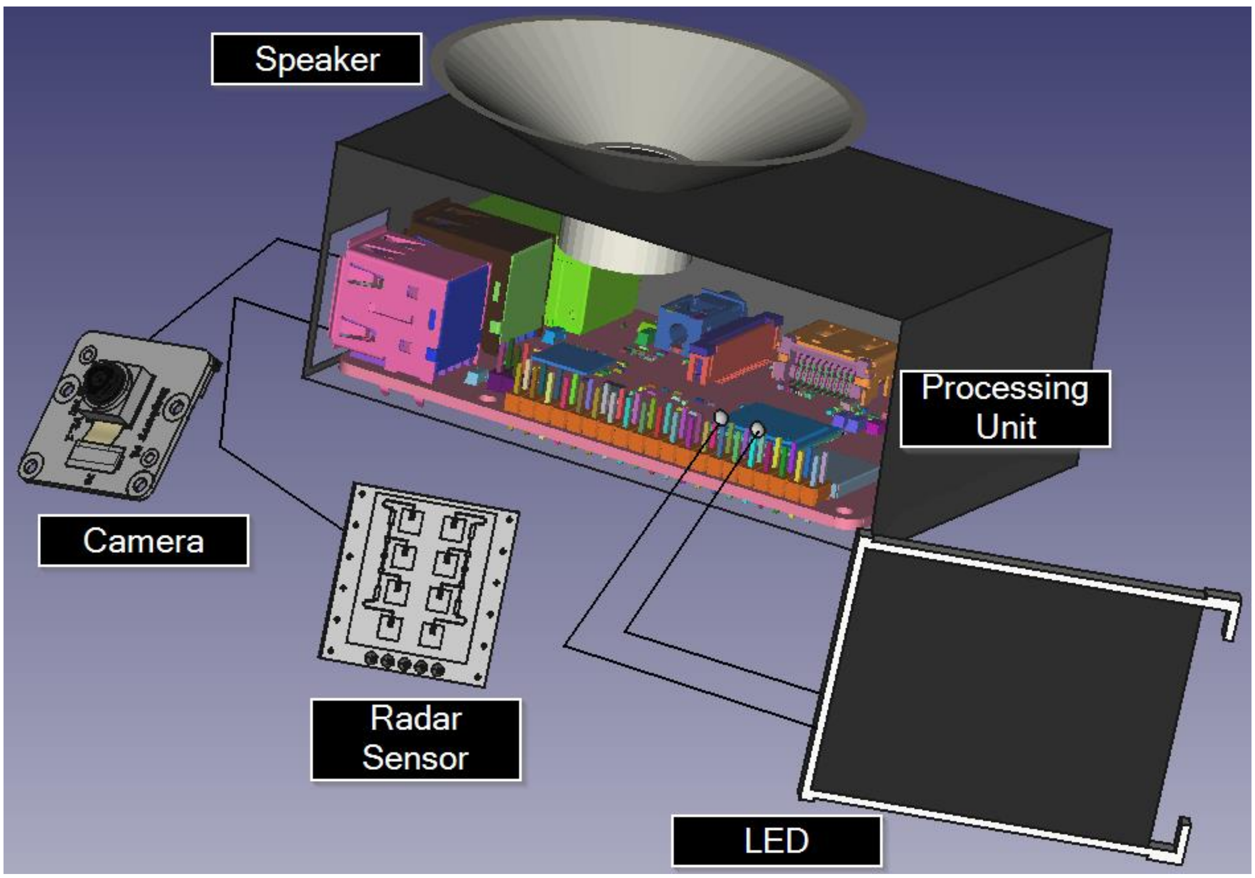

FIGURE 9-1: FOCOS' USER INTERFACE

In Fig 9.1 we see the various component of our product (the speaker is raised a bit just to show the placement of it inside the product, in the final design the speaker would be inside the box covered with a speaker mesh). To make things discoverable we have tried to make thing more visible and label where required. For example, output for 2 USB, power input and 2 holes for plugging in LED has be provided and other input has been blocked to make sure only things required are visible. On the other side where the power input is placed, we have also provided a switch with a LED to indicate the status of the device.

9.3.2 Feedback
While designing a product it is always important to show if the input by the user has been received. Without feedback, user will always wonder if has his section has created any effect or has been accepted by the product. [16]

Primary source of feedback in FoCoS is visual and audio. First is the LED switch on the main module with speaker and microcontroller, that will notify user if the system received the power and is starting up. Another visual feedback we provide is the one when the is running and it warn the user about any upcoming collision. For the audio feedback we are using inbuilt speaker (a speaker that would come with our product) and car's music system (optional). This will also warn user of any upcoming collision by producing beeps of 600hz, but the frequency of beep will be increasing or decreasing with the decreasing and increasing closing time respectively.

9.3.3 Conceptual Model
The design of a product defines a lot on how a user is going to perceive it. The human mind is a wonderful organ of under- standing, humans are always trying to perceive the events around them. [16] Our product should also be designed in a way that user could intuitively understand how to use the device's features and capabilities. Prior experience with using electronic devices, like car electronics, cameras, will help the user build a conceptual model of our device.

9.3.4 Affordance
A good design is to makes sure that right actions are perceptible and inappropriate ones invisible. The Design of Everyday Things introduced the concept of "perceived affordances", or the actions the user perceives as being possible based on how an object is presented. [16]
Different component of FoCoS affords the user, like camera has the affordance to capture, radar has the affordance to be pointed at to detect objects. As the main unit will have 2 USB inputs which also affords to be plugged in in USB cable. So, these various design choices will make our product easy to use.

9.3.5 Signifiers
Signifiers are used to provide extra information on how to use the product's main elements. FoCoS's signifier includes a clipper of the camera which signifies it needs to be hanged on the windshield. Common symbols for UI elements such as power input, power switch and labeling are also used to provide the user with extra information on what each button does.

9.3.6 Mapping
Mappings considers how intuitively UI elements are placed so that locating them to perform a specific action feels natural. As mentioned, a power switch will be placed beside the power input mapping and signifying the functionality. Similarly, other functionality would be mapped to understand the product better and making them consistent what's user expecting.

9.3.7 Constraints

The surest way to make something easy to use, with few errors, is to make it impossible to do otherwise—to constrain the choices. [16] Constraints limit the actions that the user can perform and can prevent the user from using the product inappropriately. We are providing very limited functionality to what user can do. As Raspberry Pi has multiple outputs, but we are only providing access to 2 USB ports that are needed by the user. Same for GPIO pins, user will be provided with inputs for wires for speaker and LED and other will be blocked by the enclose. This way restricting users from doing task that could cause some problem is a good way to use constraints.

9.4 Engineering Standards

To appeal to the market and provide ideal user experience for all of the main interactions, such as activation and deactivation, FoCoS's UI design will be built by and tested against the following engineering standards:

1. **IEEE 1012-2012**
   IEEE Standard for System and Software Verification and Validation [17]
2. **ISO 9241-161-2016**
   Ergonomics of human-system interaction – Part 161: Guidance on visual user-interface elements [18]

9.4.1 Safety Considerations

Safety is the most important aspect of any product, especially our product as many electronics products are involved. Out team has taken in considerations many hazards that could impact the user. To achieve high standard of safety of our product we need to follow standards as mentioned below:

1. **RoHS**
   Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment
2. **NFPA (Fire) 70**
   Temperature thresholds for the electrical components [19]

9.4.2 Internal Rules

Our team will also adhere to several common-sense guidelines while developing the user interface including of our product:

1. Containing all electronics, wires, etc. within the enclosure to abstract the device.
2. A simple interface with just a few buttons and LEDs to maintain ease of use.
3. Ensuring the device is as small and light as possible to enable portability.

9.5 Usability Testing

Our team will perform usability testing to gain knowledge on potential difficulties users could face when using our product. This will allow us to address any usability issues before releasing the product to the market. The team at Trafec will perform the usability testing phase in 2 different ways, namely analytically and empirically.

9.5.1 Analytical

For the analytical usability testing, our team will look for any errors or nuisances with respect to the user interface. After all of the new issues have been documented, the team will then discuss possible suitable solutions to each problem and determine if the time and funding spent to address the issue will be worth the cost. Once all design changes are proposed the best design will be chosen by popular vote among the team. The tests below will be performed:

Button:

1. The power switch turns on/off the device when changed the state
2. Button will have tactile and auditory feedback when pressed

LED Indicator:

1. The LED should be turn off when the device is off showing the status of the device
2. The LED should be turn on "Red" when the device is on showing the status of the device

Power Input:

1. Power adapter should be able to plug in the 12V output of the car without any force required
2. Power adapter should look like commonly used adapter in cars to be easily distinguishable
3. The Power input should be labeled to indicate the purpose
4. The power adapter is well supported to ensure the adapter does not break or weaken over time if power cable is pushed in with "excessive" force

Installation equipment:

Installation is the major part of our product. Being an after-market product, we need to make sure the installing is as easy as possible. For that we need to make sure in usability testing that the following things are attained:

1. Installing manual provides enough detail that a non-mechanic person can easily follow
2. Camera has an adhesive to stick to the windshield
3. The camera adhesive should be good enough that could last multiple installation and deinstallation
4. Radar has an adhesive that could easily installed on the front bumper of the car
5. Radar's adhesive is good enough to withstand the varying weather conditions
6. The product will come with multiple adhesive pads, so an alternative is there if the old one goes bad

9.5.2 Empirical

Feedback from our target market will play a major role in the development of our device. In the empirical testing stage, Trafec will reach out people with old car and of different age group. The users will be asked to perform series of task and related to using and installing FoCoS. The usability testing will be supervised and a "Think Aloud" session will also be carried out to figure out where the issues with UI of out product. The following list summarizes the functional exercises that the user will be asked to perform during the empirical usability testing stage:

Task 1:

Turn on the FoCoS and then turn it off.

Questions:

1. Was the turning on and off action intuitive?
2. Was there enough feedback to let you the process is completed?

Task 2:

Install the radar in the car and connect it to the main unit.

Questions:

1. How hard was it to plug in the sensor to the main unit?
2. Explain the process of installing sensor on the car and perform the task "Thinking out aloud"

Task 3:

Install the camera and LED in the car and plug it in the main unit.

Questions:

1. How hard was it to plug in the camera and LED to the main unit?
2. Explain the process of installing camera and LED on the car and perform the task "Thinking out aloud

9.6 Conclusion

As a safety tool UI is the most important part of our product as it could not work as desired. The FoCoS was designed to execute all the main processing tasks without any user input, thus minimizing any unintended use or false input. The device will be intuitive, elegant, and non-intrusive so user can focus on driving and encourage safe driving habits.

At the proof of concept stage, we will be demonstrating the processing capabilities and radar detection. At this level user interaction will be minimal, limited to visual and audio feedback. But our high fidelity prototype however, will showcase all the key user interface features of the device. The device will allow user to power it on and off, plug in sensor or camera to the main unit. The final prototype will also provide visual feedback provided by the power switch LED.

The easy to install and use approach of building FoCoS will make it a user-friendly device. Most importantly by this approach we can also let non-mechanic person install the product in his car. With this we would achieve our goal of road safety to a greater extent.