Software Requirements Specification (SRS)

Project Reverse Safety System

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1 Introduction

The Reverse Safety System is an automatic braking system designed to enhance safety by preventing collisions with pedestrians and objects while a vehicle is in reverse. This Software Requirements Specification (SRS) outlines the system's purpose, constraints, and specific requirements necessary for its development. The document includes an overall description of the Reverse Safety System, followed by detailed specifications and explanation of how these requirements are met under Specific Requirements and Modeling Requirements. Additionally, diverse scenarios and use cases will demonstrate how the system functions, and a prototype will be introduced to illustrate its key features. Finally, the References section will acknowledge any external sources used in the creation of this SRS.

1.1 Purpose

The purpose of this document is to present a detailed description of the Reverse Safety System, including hardware and software requirements. It outlines how the system is designed to enhance driver and pedestrian safety while in reverse by providing real time visual and auditory feedback with optional vibration feedback to prevent collision with surrounding objects. This document is intended for the stakeholder, designer, and developers to ensure all their requirements are met.

1.2 Scope

- The Reversing Safety System (RSS) is a critical component of a larger vehicle safety system, integrating multiple sensors to enhance reversing safety. It interacts with the central vehicle control system, braking system, and infotainment to ensure real-time object detection, audio, visual, and haptic warnings, and automatic braking when necessary.
- As part of the broader automotive safety architecture, RSS processes sensor data (Lidar, ultrasonic, pressure sensors, and cameras), analyzes potential obstacles, and communicates with the vehicle's braking and alert systems to prevent accidents.

- The main objective of RSS is to prevent any injury by detecting objects and pedestrians using multiple sensors it contains and notifying the driver to brake the car or even automatically braking the car when the car is about to hit the objects or pedestrians.

1.3 Definitions, acronyms, and abbreviations

Charged coupled Device (CCD)	Improve the ability for cameras in low light sensors
Back of Car	Side of the car opposite to the driver windshield
In-car display	A screen inside the vehicle that provides visual feedback
Decibel (dB)	Unit of measurement for sound intensity
nits	Unit of measurement used to quantify the luminance
Ultrasonic sensor	Sensor that uses high-frequency sound waves to detect objects and measure distances
Lidar sensor	Sensor that uses laser pulses to measure distances
Air pressure sensor	A pressurized and bendable tube that senses the change of the internal pressure inside of the tube when it gets bent. It is located right inside of the back bumper.
G-force (g)	Unit of acceleration equal to earth gravity
Mile per hour (mph)	Speed at which a car is traveling
Central Controller	Primary computing unit in vehicle that processes data and monitors sensor status
Automatic braking	Automatically applies the brakes to prevent/reduces collections

1.4 Organization

In the next section, Overall Description, provides general functions, characteristics, Assumptions, and deferred requirements of the system. Section 3, Specific Requirements, is enumerated system requirements that are needed for the system. Section 4, Modeling Requirements, provides visual representations of the system. Section 5, Prototype, meaningful use cases developed for the system including any explanation. Section 6, References, cities outside sources used to create this document.

2 Overall Description

The following section will introduce a detailed background of the Reverse Safety System. It includes the interface, functions, user characteristics, constraints, and deferred requirements. These are context information that is needed to be considered before requirements of the system are made.

2.1 Product Perspective

The Reversing Safety System (RSS) is a critical component of a larger vehicle safety system, integrating multiple sensors and interfaces to enhance reversing safety. It interacts with the central controller system, braking system, and driver interface, ensuring real-time object detection, issuing warnings, and applying automatic braking when necessary.
As part of the broader automotive safety architecture, RSS processes sensor data (Lidar, ultrasonic, pressure sensors, and cameras), analyzes potential obstacles, and communicates with the vehicle's braking and alert systems to prevent accidents. Below is an overview of the system's interface constraints:

- Memory: Requires sufficient storage for sensor logs and real-time processing.
- Operations: Must process sensor data within 100ms intervals for immediate responsiveness.
- Site Adaptation: Can be calibrated for different vehicle models with adjustable sensitivity settings based on vehicle

2.2 Product Functions

The Reversing Safety System (RSS) is designed to enhance vehicle safety while reversing by performing the following key functions:

- Object Detection: Uses Lidar, ultrasonic, pressure sensors, and cameras to detect objects within 120 degrees of the rear center and up to 40 feet away.
- Automatic Braking: Engages the braking system when an object is detected within three inches of the vehicle.
- Driver Alerts: Provides visual (dashboard display), auditory (45dB alerts), and optional seat vibration feedback to notify the driver of nearby obstacles.
- Sensor Monitoring: Continuously checks the status of sensors every 500ms, disabling faulty ones and notifying the driver of malfunctions.
- Environmental Adaptation: Adjusts detection and alerts based on lighting conditions, sensor visibility, and external obstructions (e.g., activating windshield wipers if Lidar visibility is reduced).
- User Overrides: Allows drivers to override automatic braking unless a collision is detected.

2.3 User Characteristics

The Reversing Safety System is designed for drivers, vehicle technicians, and fleet managers, each with different expertise and interaction levels.

- Drivers include personal and commercial vehicle operators with low to moderate technical skills, requiring an intuitive interface with audio, visual, and vibration alerts. Technicians have high expertise in vehicle diagnostics and require system logs, sensor calibration tools, and manual overrides for maintenance.
- Fleet managers oversee multiple vehicles and require automated reports, system status updates, and telematics integration to ensure the safety of the entire fleet.

The system must function in various weather conditions and account for sensor malfunctions and unpredictable pedestrian behavior by using redundant detection methods. It also supports accessibility features, such as vibration alerts for hearing-impaired drivers.

2.4 Constraints

The Reversing Safety System operates within several technical, regulatory, and environmental constraints to ensure safety, reliability, and compliance.

2.4.1 Regulatory and Compliance Constraints

- The system and the automatic braking must comply with ISO 26262 (Automotive Safety) [1], and NHTSA regulations [2] .
- Automatic braking allows manual override, except during collision scenarios.

2.4.2 Hardware and Environmental Constraints

- The system must integrate with existing vehicle components (braking system, power supply, onboard computer).
- Sensor placement is restricted to the rear bumper, windshield, and license plate to ensure effective detection.
- The system must function in various weather conditions (rain, fog, snow, wind) and adjust reliance on multiple sensors to prevent false detections.

2.4.3 Performance Constraints

- The system must process sensor data within 100ms for real-time alerts and braking.
- Camera resolution must be at least 1080p with 600 nits brightness for clear visibility.
- Automatic braking must activate when an object is within 3 inches, with braking force adjusted based on risk level.

2.4.4 User Accessibility Constraints

- Sound alerts are limited to 45 dB, with vibration feedback (1 Newton) for hearing-impaired drivers.
- The display must support brightness adjustments for visibility in different lighting conditions.

2.4.5 System Failure Handling Constraints

- Central controller verifies sensor functionality every 500ms and disables faulty sensors.
- If a sensor fails, the system must notify the driver and rely on the other sensors.
- The braking system must remain operational even if other components fail.
- If all sensors fail, the driver must still be able to reverse while RSS is deactivated.

2.4.6 Interoperability Constraints

- The system must integrate with vehicle telematics, fleet monitoring systems, and remote diagnostics.

2.5 Assumptions and Dependencies

2.5.1 Hardware Assumptions

- The vehicle has a central controller processing sensor data within 100ms.
- Multiple sensors (LiDAR, camera, ultrasonic, pressure) provide redundant detection.
- A CCD sensor camera is used for better performance in low-light and diverse weather.
- The vehicle includes automatic braking and a sound system for 45 dB alerts.
- The central controller system never fails.

2.5.2 Software Assumptions

- The central controller monitors sensors and disables faulty components.
- Sensor data is processed every 100ms for real-time alerts and braking.
- Multi-sensor validation helps differentiate real obstacles from false positives.
- The display provides real-time imaging with object detection indicators.

2.5.3 Environmental Assumptions

- The system functions in rain, snow, fog, winds, daytime and nighttime
- Obstructed cameras will be compensated by other sensors.

2.5.4 User Interaction Assumptions

- Drivers understand vehicle operations and can respond to alerts.
- Hearing-impaired drivers rely on seat vibration alerts (1 Newton).
- Drivers can override automatic braking unless a collision is detected.

2.5.5 System Dependencies

- The system relies on real-time sensor data and multi-sensor redundancy.
- Braking system must function properly for emergency stops.
- Pedestrian detection depends on sensor coverage, with some movements being unpredictable.

2.6 Deferred Requirements

- A phone application that shows diagnostics relating to the systems hardware
- Ability to change notification sound of a detected object
- Improved hardware notification system that tells the driver what specific hardware is inactive and the reason for it

3 Specific Requirements

In this section, we are going to introduce specific requirements of the Reverse Safety System with sources of uncertainties. Sources of uncertainty will be introduced after specific requirements.

3.1 Requirements

Index : refinement, correction, new requirements, requirements from other teams

1. The car must be able to detect an object up to 50 degrees from the back and center of the car, from a distance of at least 40 feet in any weather conditions on a flat, unobstructed surface.
   1.1. The back of the car is defined to be the side of the car opposite to the driver's windshield.

2. The car should activate the automatic braking system when it detects an object is three inches away or projected to be under three inches no matter what sensor picked it up.
   2.1. The physical pedal should move to indicate how much braking the car is applying.

Template based on IEEE Std 830-1998 for SRS. Modifications (content and ordering of information) have been made by Betty H.C. Cheng, Michigan State University (chengb at msu.edu)

3. When the object is detected and shown in the car display, it needs to be indicated like below:
    3.1. If the object is within 3-6 feet of the car, a yellow box needs to highlight surrounding the object on the in-car display that shows a back-up camera view. If the object is within 3 feet of the car, a red box needs to be highlighted surrounding the object on the in-car display that shows a back-up camera view.

4. When the car is in reverse, the car should have a sound signal of 45 dB to alert the driver in situations that the car needs to alert the driver about detected objects within 6 feet of the car.
=> The car's sound signal to alert the driver will be 45dB when the car is in reverse.
    4.1. When the car is making a sound signal to alert the driver, other active sounds from the system should be reduced to 3dB.
    4.2. There is an additional option that allows the driver to activate a seat vibrator to notify the driver of an incoming obstacle
        4.2.1. This is helpful for drivers who are deaf
        4.2.2. The vibration should be 1 Newton.
            4.2.2.1. This can be adjusted by the driver

5. The car should have cameras placed around the car so the driver can see at least 4 feet in all cardinal directions around the car, and at least two vertical feet from the base of the tires in the 4 feet around the car. Surround view cameras showing 360 degrees surrounding environments will help prevent accidents [3].
    5.1. The cameras should either be 1080p [4] or 4k video and deliver each frame in less than 100ms. The cameras should be able to provide at least 600 nits of brightness.
        5.1.1. The screen should be able to adjust the brightness depending on user input to account for changing environment conditions.
        5.1.2. The camera should use charged coupled device (CCD) sensors for image recognition as it works well in different lighting conditions (daytime vs nighttime)

6. The car should have a CCD camera at the back of the car capable of sensing objects within 10 feet around the left and right back corners of the car.
    6.1. 10 feet is chosen as it is twice the estimated stopping distance of cars at 10 mph [4].

7. The car should have an ultrasonic sensor one inch above the rear license plate and process the income data at 100ms.

7.1. If an object is under an inch away from the most extruded point of the back of the car, moving or stationary when the car is moving backward, stop the car for 2 sec before allowing any further backward progress to be made.

7.2. 45-dB sound notification needs to be activated as the object is getting closer to the car from the moment the object is within 3 feet from the car.

8. The car should have a Lidar sensor installed behind the rear view windshield wiping area on the inside of the car and will send out a response every 100ms.

8.1. It is installed 1 inch from the pivot of the wiper blade, within the area that the wiper cleans.

8.2. If the return rate of the laser is below 85% three times in a row consider this as a failure, trigger the windshield wipers.

8.2.1. Windshield wipers can only activate a maximum of 3 times in a single backup session by lidar sensor if the return rate does not improve by activating the windshield wipers.

9. The car should have crash sensors that read the air pressure. If any of the air pressure sensors read a g-force of 2 g's or greater, then the car should automatically press the brakes. 2g is a calculated result of a car crash assuming the car speed is 3mph [6].

9.1. We are assuming that the car can go from 3 mph to 0 mph within .16 seconds to achieve these results based on. We are assuming 3 mph because it is the average speed of the backing vehicles from NHTSA's special crash investigations of 58 back-over cases [7].

9.2. There will be three crash sensors all located on the left, middle, and right of the rear bumper.

10. The car should have a central controller that monitors all safety features of the car, such as the cameras, sensors, etc. It should monitor all features every .5 seconds and determine if the safety feature is able to fulfill its described capability all the time as long as the car is turned on and in reverse.

11. In the case of a safety feature no longer fulfilling its capabilities, the car will disable the safety feature and display a 5 second message on the driver's dashboard and 45-dB notification informing the driver that the feature is no longer active every time the car is turned on and the car gets into reverse mode. After the 5 second message disappears, it is replaced by a lighted up constant icon on the dashboard.

11.1. The 45-dB sound notification can only be activated maximum 3 times in 5 minutes after the last activation.

11.2. If the on-board computer determines that the disabled feature is meeting its requirements again, it will enable and notify the driver the same way as when disabled.

11.3. If the vehicle is shifted into reverse (R) while the system is inactive, the same warning message and sound notification shall be triggered.

11.4. If none of the sensors (LiDAR, ultrasonic, camera, and pressure) are operational, the entire RSS should automatically be deactivated.

12. The system shall allow the driver to override automatic braking by applying the brake pedal, except in cases where a collision has been detected.

13. The RSS should activate automatically when the vehicle is shifted into reverse gear (R).

13.1. The system must begin processing sensor data within 100ms after activation.

13.2. The camera feed and visual indicators on the display should activate simultaneously with the system.

14. The RSS shall deactivate automatically when the vehicle is shifted out of reverse gear (R).

3.1.1 Method

Our method for determining which use cases should be included was to determine which requirements were needed, and what details were needed to ensure those requirements were safe enough. Any information that was not included in either member's assignments but needed, was added at the end.

3.2 Sources of Uncertainty

1. Environmental Uncertainty

Weather and lighting conditions, such as wind, rain, fog, snow, daytime, nighttime, etc. It can affect the camera system's capability by skewing the image quality of the camera. It can affect the pressure system when the weather gets extraordinarily harsh such as tornadoes or hurricanes.

1.1. The camera system allows the driver to understand what objects are being detected from the system through visual imaging. For instance, if the camera feed is detecting an object while this part of the system is down the user is having blind faith in the system without having any visual indicators to support this indication. In addition to just affecting the camera system, weather can impact the pressure system with harsh winds, if the car is in an area that is experiencing this the car will not move since it believes that an object is being hit.

1.2. The uncertainty is detected by the central controller system. The central controller checks the image quality to see if the image is a high-resolution image, which means it is 1080p or 4k. If it is below this threshold, then the central controller determines that weather conditions are affecting the camera system. With the high winds activating the pressure sensors, the central controller compares the pressure sensor data to the other sensors to determine if an object really is there or if it's just wind.

1.3. The weather conditions uncertainty is mitigated in two ways. First, a charged coupled device (CCD) camera is utilized to perform better in various lighting and weather conditions. The second way is the use of the ultrasonic sensor component which the central controller will use to determine the wind speed and use the other image data to verify if the pressure sensors were activated by wind or an actual object.

2. System Reliability and Hardware Failures

The system consists of both software and hardware, working together to ensure reliable performance. It can be broken or cannot function correctly. Nobody can guarantee the machine will be completely free from the risk of being broken while using.

2.1. With software and hardware there can be many different problems that can cause a malfunction of the system. For example, if the Lidar sensor has debris in front of the sensor this could cause the laser to get lost. Hardware can also become damaged and unavailable due to car accidents, causing the system to be a danger as it can lead to false and missed objects.

2.2. This uncertainty is detected by the central controller. The central controller will continuously run tests to verify the functionality of the sensors and safety features and whenever it determines that a sensor is non operational then it will disable the system and notify the driver.

2.3. This is mitigated by utilizing multiple overlapping views with different sensors such as camera sensors, lidar sensors, ultrasonic sensors, and pressure sensors. Since there is no hierarchy among sensors, even if one sensor goes down, another sensor can still detect an object using its own method. For example, even if the camera, lidar, and ultrasonic sensors all go down, the pressure sensor will still be able to detect an impact with an object.

3. Pedestrian Behavior Uncertainty

They are human and thus their actions cannot be reliably predicted. A pedestrian might be behind an obstacle obstructing the view of them a few feet over, then the driver and sensor of a vehicle won't be able to detect the pedestrian. If the pedestrian quickly walks out from behind the car, a driver and sensors might not have time to react.

3.1. For pedestrians and their unpredictability make it hard for software and hardware to predict their movement in a constant manner especially only visible for a split second allowing for a collation to happen if the computer is not processing the incoming data quickly enough. To help lower the chance of this collision from happening is to have the computer process the incoming data from all sensors every 100 MS to give the car time to react to new scenarios.

3.2. This uncertainty is detected with the help of the central controller. The central controller takes all information from the array of sensors and calculates any potential objects in the field of view. We included multiple sensors to ensure maximum coverage around the car.

3.3. We used sensors that can work in different conditions and in different ranges, some with overlapping views, to ensure that even if one sensor misses a pedestrian doing something unexpected, another can give the correct information. The sensors include the lidar, camera, pressure, and ultrasonic sensors.

4 Modeling Requirement

4.1 Use case diagram

Figure 4.1 below illustrates high-level interactions between various actors and the reverse safety system. It highlights key use cases, the actors involved, and the system's boundary, offering a clear overview of its responsibilities.

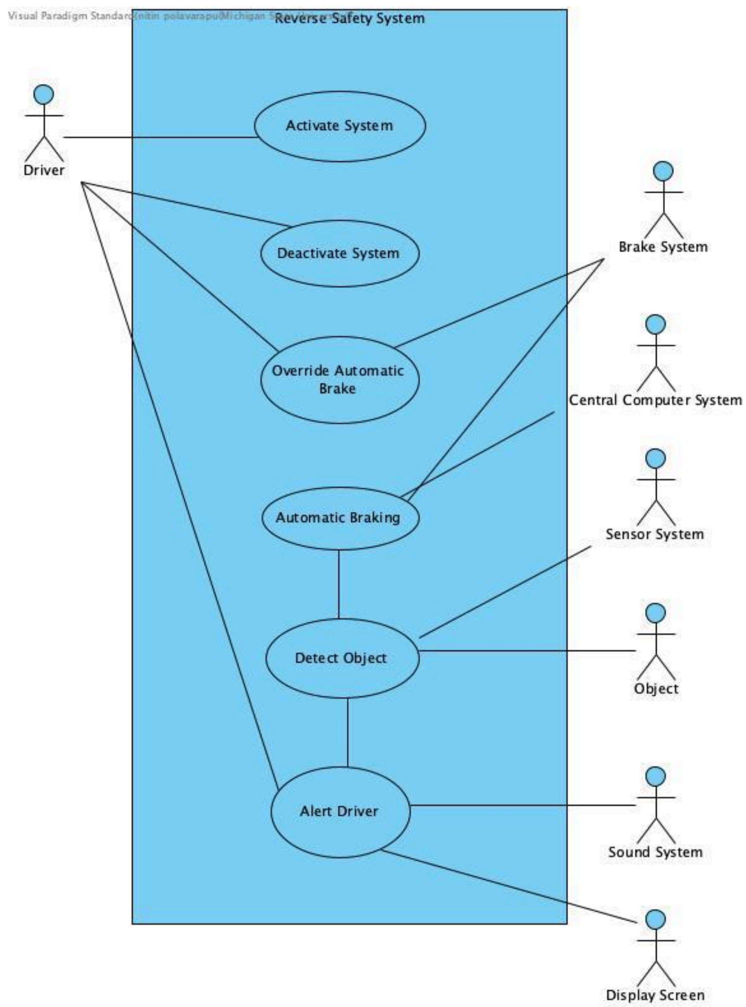

Figure 4.1: Use case diagram

4.1.1 Use case table

Use case tables describe each use case in the use case diagram in section 4.1. Each table includes use case, actors, description, type, use cases that are in relationship of includes and extends with the use case, use cases that are connected to the use case and cross references from requirements.

Use Case	Detect Object
Actors	Sensor, Object
Description	To detect objects including pedestrians using camera, Lidar, Ultrasonic, and pressure sensor systems to prevent injuries
Type	Primary
Includes	None
Extends	None
Cross-refs	1, 3, 4, 5, 6, 7, 8, 9, 10
Use cases	Alert Driver, Automatic Braking

Use Case	Override Automatic Braking
Actors	Driver
Description	Allows the driver to override the automatic control and prioritize manual input when there is a conflict with the car's automated system. The override is restricted in cases where a collision has been detected.
Type	Primary
Includes	None
Extends	Brake, Reverse
Cross-refs	8,9, 12
Use cases	None

Use Case	Alert Driver
Actors	Driver, Sound System, Display Screen
Description	This handles visual alerts, audio alerts, and optional vibration alerts for drivers while being careful not to unnecessarily distract drivers. This helps drivers acknowledge if the safety features are available or not and if the car detected objects or not. While indicating through audio, it should reduce the system volume for other sounds. The visual indications should have boxes around them to allow the driver to focus on the detected objects. Optionally, if the driver turns on the vibration alert setting, the driver seat will be vibrated to alert the driver.
Type	Primary
Includes	None
Extends	None
Cross-refs	4, 11
Use cases	Detect Object

Use Case	Activate System
Actors	Driver
Description	The RSS is activated when the vehicle is shifted into reverse. This is to prevent safety features from activating and distracting the driver in other situations.
Type	Primary
Includes	None
Extends	None
Cross-refs	10
Use cases	None

Use Case	Disable System
Actors	Driver, Central Controller System
Description	The RSS can be disabled in two scenarios. The first is when the driver shifts the car out of reverse and the second is when the central controller determines the reverse safety system is unavailable due to damaged hardware/software. This happens when ALL sensors are deemed damaged and unreliable.
Type	Primary
Includes	None
Extends	None
Cross-refs	10, 11
Use cases	None

Use Case	Automatic Braking
Actors	Brake System, Central Controller System
Description	Automatically brakes the car and presses the brake pedal when an object is detected within a certain range. The vehicle should use its sensors to detect objects and calculate their distance from the vehicle. When an object is detected within 3 inches of the vehicle the automatic braking system should activate, stopping the car. Once stopped the driver should again be able to resume driving if they chose to do so. The vehicle should also automatically brake if the vehicle detects a collision. If the vehicle detects more than 2 G's from the pressure sensor, it should automatically brake.
Type	Primary
Includes	None
Extends	None
Cross-refs	1, 2, 9

Use cases	Detect Object

Use Case	Adapt to Weather
Actors	Sensor System
Description	Adjusts detection and alerts based on lighting conditions, sensor visibility, and external obstructions. This includes activating windshield wipers if Lidar visibility is reduced and adjusting display brightness based on lighting conditions.
Type	Primary
Includes	None
Extends	None
Cross-refs	5.1, 8.2.1
Use cases	Detect Object

4.1.2. Old version of use case diagram

Figure 4.1.2 below showcases the original use case diagram. However after further consideration, this figure was replaced with Figure 4.1 which provides a high level overview of the system. Figure 4.1.2 delved too deeply into the system's responsibilities, making it unsuitable for conveying a broad overview.

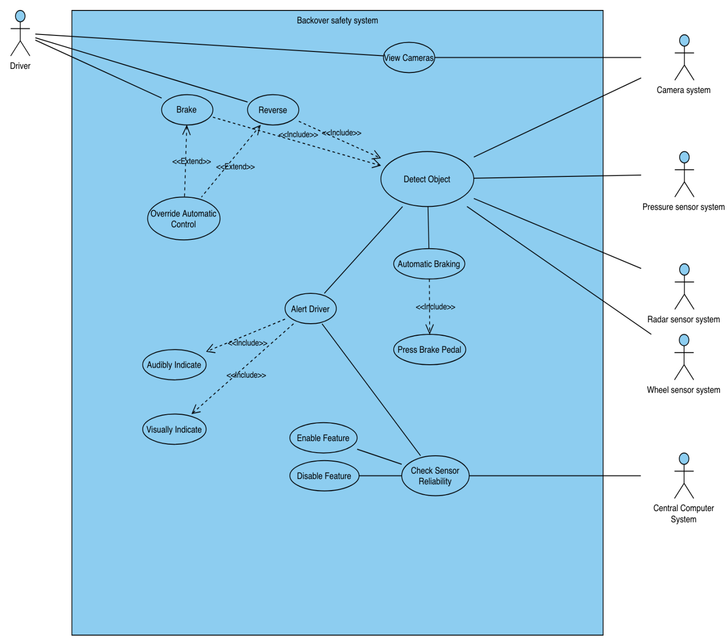

figure 4.1.2: Old use case diagram

4.2. Class diagram

Figure 4.2 shown below visualizes our systems object-oriented classes. It highlights the key classes, attributes, operations, associations of the system thus giving a clear overview of the softwares implementation.

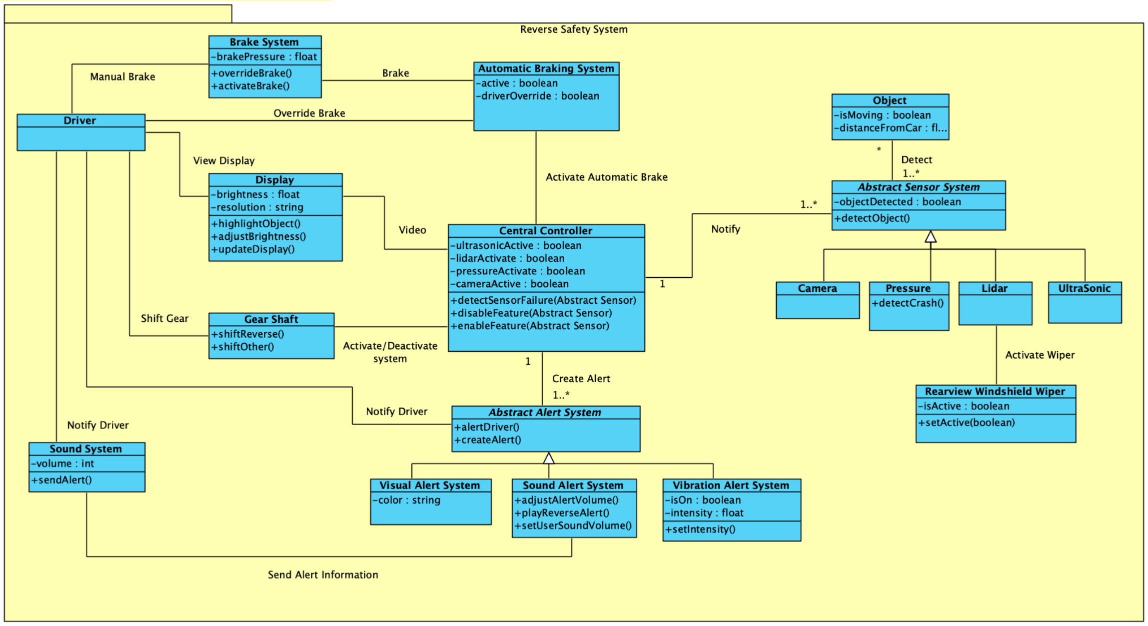

figure 4.2: Domain diagram

4.2.1 Class diagram description

Class Name	Central Controller
Description	Responsible for managing the overall system. Duties include verifying sensors are operational, determining abs activation, managing driver notifications, sending backup camera video feed to display.
Export Control (Yes/No)	No
Associations	Abstract Sensors, Automatic Braking System, Abstract Alert System, Display
Aggregations	None
Compositions	None
Generalization	None
Attributes	ultrasonicActive : bool, lidarActive : bool, pressureActive : bool, cameraActive : bool

Operations	updateDisplay(), detectSensorFailure(Abstract Sensor), disableFeature(Abstract Sensor), enableFeature(Abstract Sensor)

Class Name	Abstract Alert System
Description	Base parent class that serves as the blueprint for the three types of alerts in the system
Export Control (Yes/No)	No
Associations	Central controller, driver
Aggregations	None
Compositions	None
Generalization	Parent class of visual alert system, sound alert system, vibration alert system
Attributes	None
Operations	alertDriver()

Class Name	Object
Description	Moving/Motionless objects that will be detected by the system while the system is in reverse
Export Control (Yes/No)	No
Associations	Abstract sensors
Aggregations	None
Compositions	None
Generalization	None
Attributes	isMoving : bool, distanceFromCar : float
Operations	None

Class Name	Visual Alert System
Description	A visual alert for the car. Sends an alert to the car's display that the driver looks at.
Export Control (Yes/No)	No
Associations	None
Aggregations	None
Compositions	None
Generalization	Child Class of Abstract Alert System
Attributes	Color: string
Operations	None

Class Name	Sound Alert System
Description	An audible alert for the car. Sends an alert to the sound system
Export Control (Yes/No)	No
Associations	Sound System
Aggregations	None
Compositions	None
Generalization	Child Class of Abstract Alert System
Attributes	None
Operations	adjustAlertVolume() playReverseAlert() setUserSoundVolume()

Class Name	Vibration Alert System

Description	A vibration alert for the car. Vibrates the driver’s seat
Export Control (Yes/No)	No
Associations	None
Aggregations	None
Compositions	None
Generalization	Child Class of Abstract Alert System
Attributes	isOn: Boolean Intensity : float
Operations	setIntensity()

Class Name	Sound System
Description	A controller for the sound system of the car including interior speakers
Export Control (Yes/No)	Yes
Associations	Driver, Sound alert system
Aggregations	None
Compositions	None
Generalization	None
Attributes	Volume: int
Operations	None

Class Name	Abstract Sensor
Description	Base parent class that all four sensors extend from.
Export Control (Yes/No)	No

Associations	Central Controller, Camera, Pressure, Lidar, UltraSonic
Aggregations	None
Compositions	None
Generalization	Parent class of Camera, Pressure, Lidar, and UltraSonic
Attributes	objectDetected: boolean
Operations	detectObject()

Class Name	Camera
Description	A sensor that detects objects using visual input and provides a real-time feed to the driver.
Export Control (Yes/No)	No
Associations	None
Aggregations	None
Compositions	None
Generalization	Child of Abstract Sensor class
Attributes	Inherits objectDetected from Abstract Sensor
Operations	Inherits detectObject() from Abstract Sensor

Class Name	Pressure Sensor
Description	A sensor that detects objects based on pressure changes
Export Control (Yes/No)	No

Associations	Central controller
Aggregations	None
Compositions	None
Generalization	Child of Abstract Sensor class
Attributes	Inherits objectDetected from Abstract Sensor
Operations	Inherits detectObject() from Abstract Sensor, detectCrash()

Class Name	Ultrasonic
Description	A type of sensor that detects objects in its range using ultrasonic sound waves and provides a real-time feed to the driver.
Export Control (Yes/No)	No
Associations	Abstract Sensors
Aggregations	None
Compositions	None
Generalization	Child of Abstract Sensor class
Attributes	Inherits objectDetected from Abstract Sensor
Operations	Inherits detectObject() from Abstract Sensor

Class Name	Lidar
Description	A type of sensor that detects objects in its range using laser light and provides a real-time feed to the driver.

Export Control (Yes/No)	No
Associations	Abstract Sensors, Rear View Windshield Wiper
Aggregations	None
Compositions	None
Generalization	Child of Abstract Sensor class
Attributes	Inherits objectDetected from Abstract Sensor
Operations	Inherits detectObject() from Abstract Sensor

Class Name	Rearview Windshield Wiper
Description	Wipes the windshield when it gets signals to operate and is responsible to make the windshield clear.
Export Control (Yes/No)	Yes
Associations	Lidar
Aggregations	None
Compositions	None
Generalization	None
Attributes	isActive:boolean
Operations	setActive(boolean)

Class Name	Driver
Description	The person who operates the vehicle, receives alerts, responds to system feedback, and can override automatic controls.

Export Control (Yes/No)	No
Associations	Sound System, Automatic Braking System, Display, Brake System, Abstract Alert System, Gear Shaft
Aggregations	None
Compositions	None
Generalization	None
Attributes	None
Operations	brake() overideBrake() shiftGear()

Class Name	Display
Description	Visual interface that provides feedback to the driver
Export Control (Yes/No)	Yes
Associations	Driver, Central Controller
Aggregations	None
Compositions	None
Generalization	None
Attributes	brightness: float resolution: string
Operations	hightlightObject() adjustBrightness() updateDisplay()

Class Name	Automatic Braking System
Description	The system that automatically applies brakes when an obstacle is detected
Export Control (Yes/No)	No
Associations	Driver, Central Controller, Brake system
Aggregations	None
Compositions	None
Generalization	None
Attributes	active : boolean driverOverride: boolean
Operations	activate_brake()

Class Name	Brake System
Description	The system is responsible for the normal braking system to make a car stop.
Export Control (Yes/No)	Yes
Associations	Driver, Automatic Braking system
Aggregations	None
Compositions	None
Generalization	None
Attributes	brakePressure : float
Operations	None

Class Name	Gear Shaft

Description	Controls the activation and deactivation of our safety system
Export Control (Yes/No)	Yes
Associations	Driver, Central Controller
Aggregations	None
Compositions	None
Generalization	None
Attributes	None
Operations	shiftReverse(), shiftOther()

4.3. Sequence diagram

As shown in figure 4.3.1, the driver shifts the car to reverse, the gear shift notifies the central controller to activate. The central controller checks to see if any of the sensors are broken/failed. After checks have been completed see if any object has been detected. Then update the display with the new camera feed. Repeats checks for an object until the driver shifts out of gear, sending the deactivated single to the central controller.

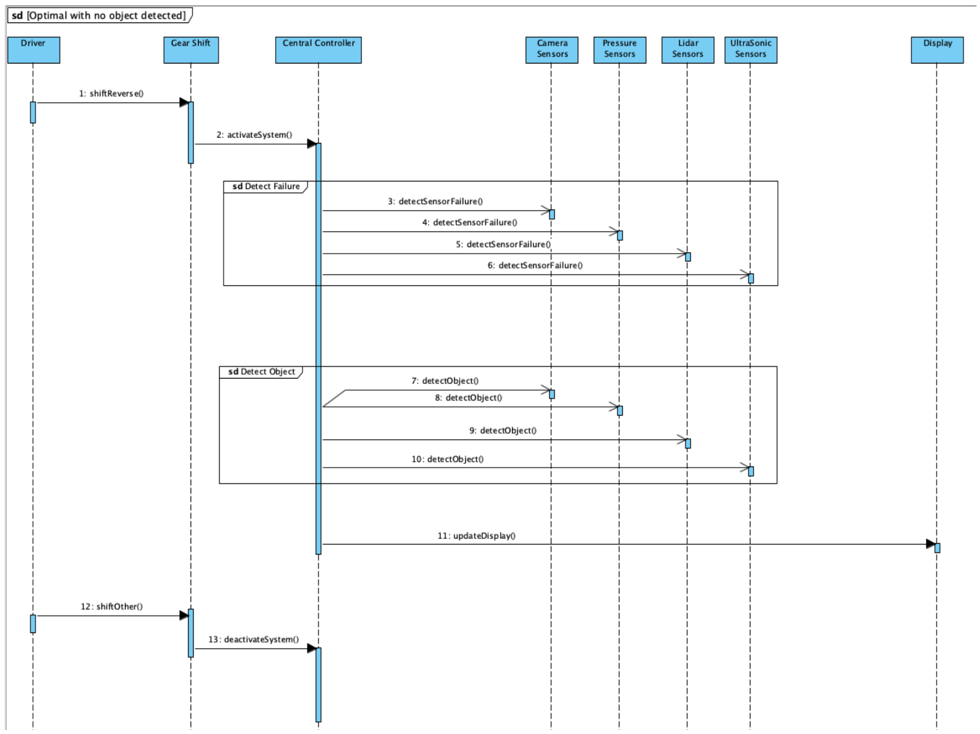

Figure 4.3.1 No object was detected

As shown in figure 4.3.2, the driver shifts the car to reverse the gear shift and notifies the central controller to activate. Once reverse is engaged, the central controller activates the sensor system and performs a check for any sensor failures. If all sensors are functioning correctly, the camera, pressure, lidar, and ultrasonic sensors begin scanning the area behind the vehicle. When an object is detected within the 3-foot range, the system highlights the detection on the display and alerts the driver through a sound notification. The system is deactivated once the car is shifted out of reverse.

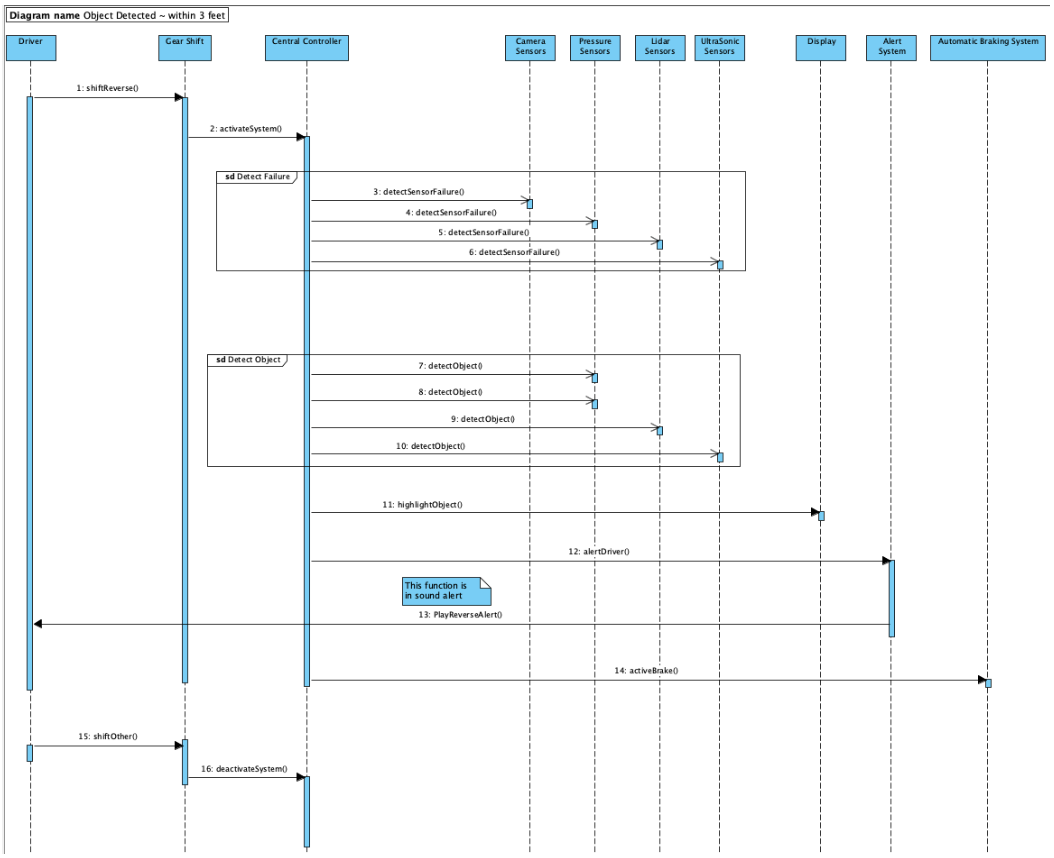

Figure 4.3.2 Object detected within 3 feet

As shown in figure 4.3.3, the driver shifts the car to reverse the gear shift and notifies the central controller to activate, The central controller activates the sensor system and checks for any sensor malfunctions. If all sensors are operational, the camera, pressure, lidar, and ultrasonic sensors begin scanning the rear surroundings. When an object is detected between 3 and 6 feet, the system highlights the object on the display and generates an alert, which is then sent to the driver through the alert system. The system is turned off once the vehicle is shifted out of reverse.

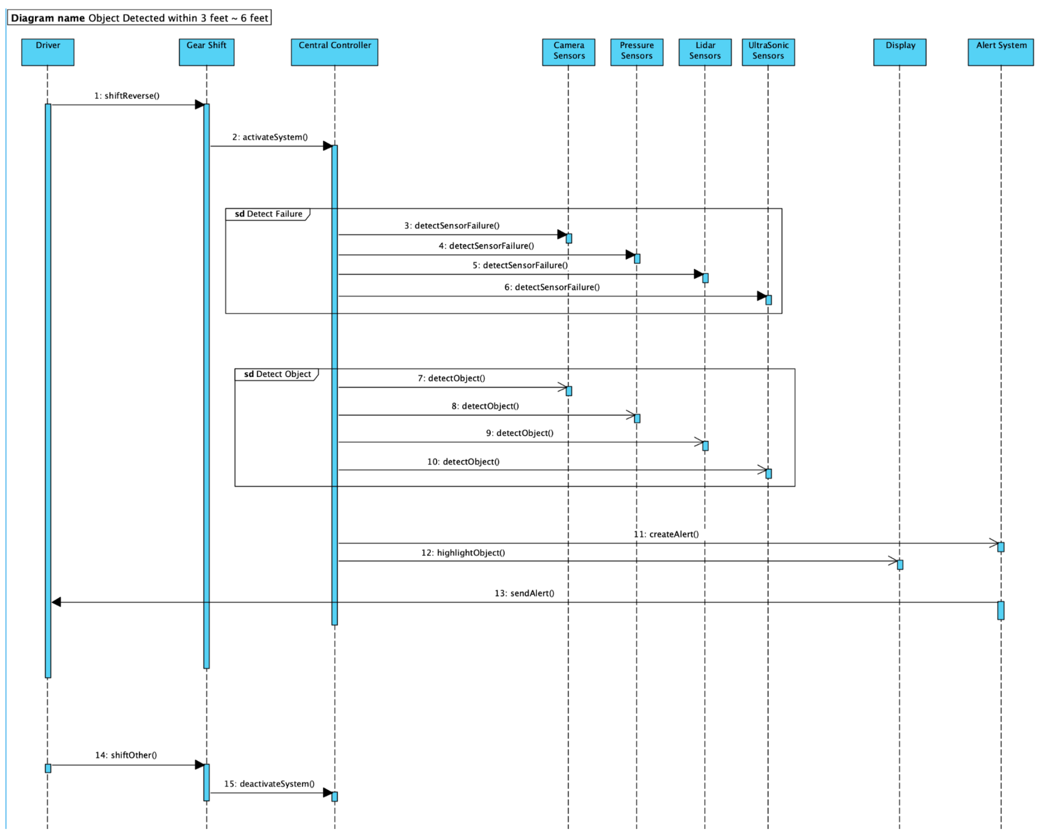

Figure 4.3.3 Object within 3 to 6 feet

As shown in figure 4.3.4, the driver shifts the car to reverse, the gear shift notifies the central controller to activate. The central controller checks to see if any of the sensors are broken/failed. After checks have been completed see if any object has been detected. If a sensor misidentifies something as an object, update the display of the car and see if it is within 3 inches of the vehicle. If so, activate the automatic braking system. Repeat this process until the driver shifts out of gear sending the message to the central computer to deactivate the sensors in the system.

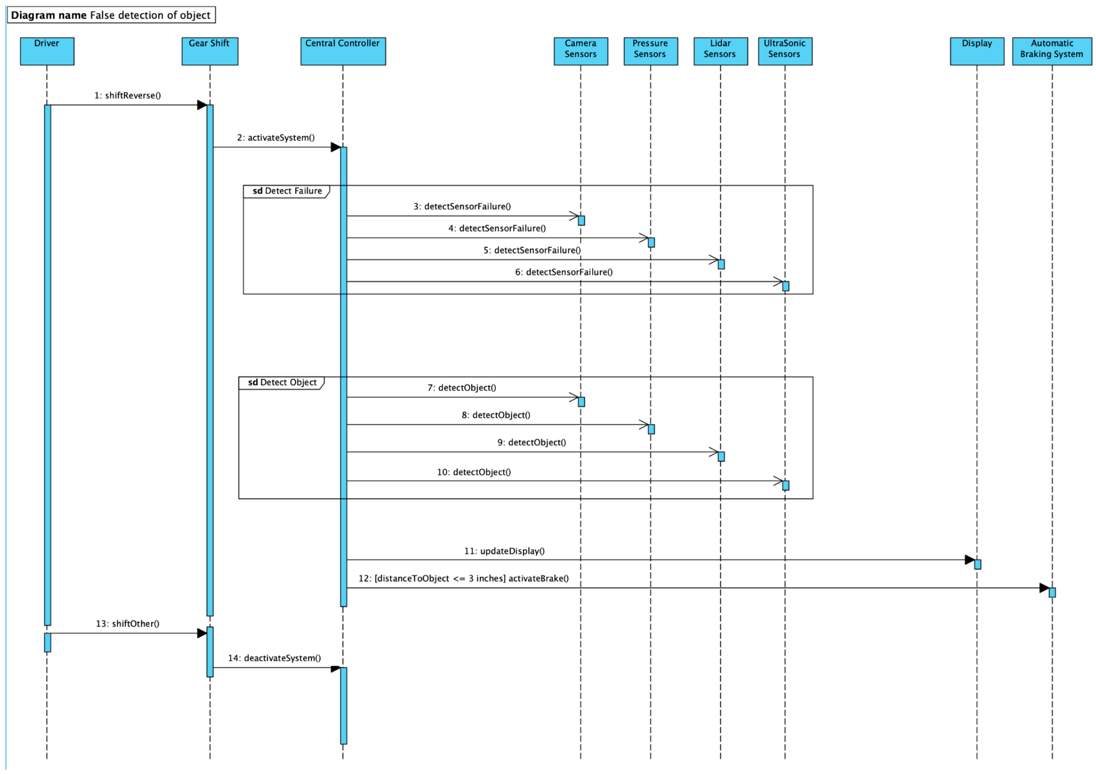

Figure 4.3.4 false detection of object

As shown in figure 4.3.5, the driver shifts the car to reverse, the gear shift notifies the central controller to activate. The central controller checks to see if any of the sensors are broken/failed. After checks have been completed see if any object has been detected. If an object is protected to cause a crash notify the central controller and activate automatic braking system

Then update the display with the new camera feed. Repeats checks for an object until the driver shifts out of gear, sending the deactivated single to the central controller.

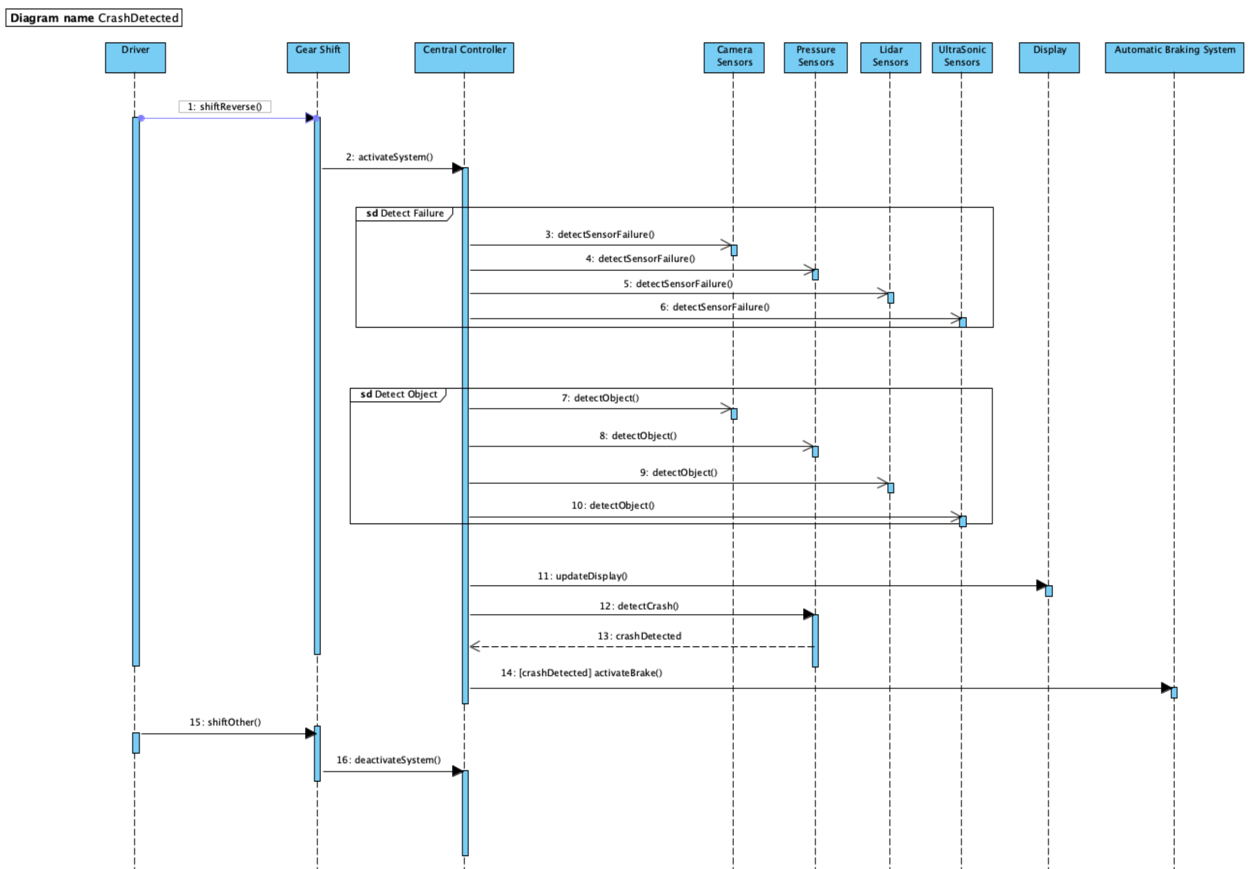

Figure 4.3.5 Crash detected

As shown in figure 4.3.6, the driver shifts the car to reverse, the gear shift notifies the central controller to activate. The central controller checks to see if any of the sensors are broken/failed. If a sensor is found to be broken, the central controller disables its features. (If all sensors are non-functional, the system is automatically deactivated) It then generates an alert for each broken sensor and updates the display system accordingly. The alert system forwards the notification to the sound system. The driver can then view the alert on the display system. The alert system delivers the sound or vibration alert to the driver.

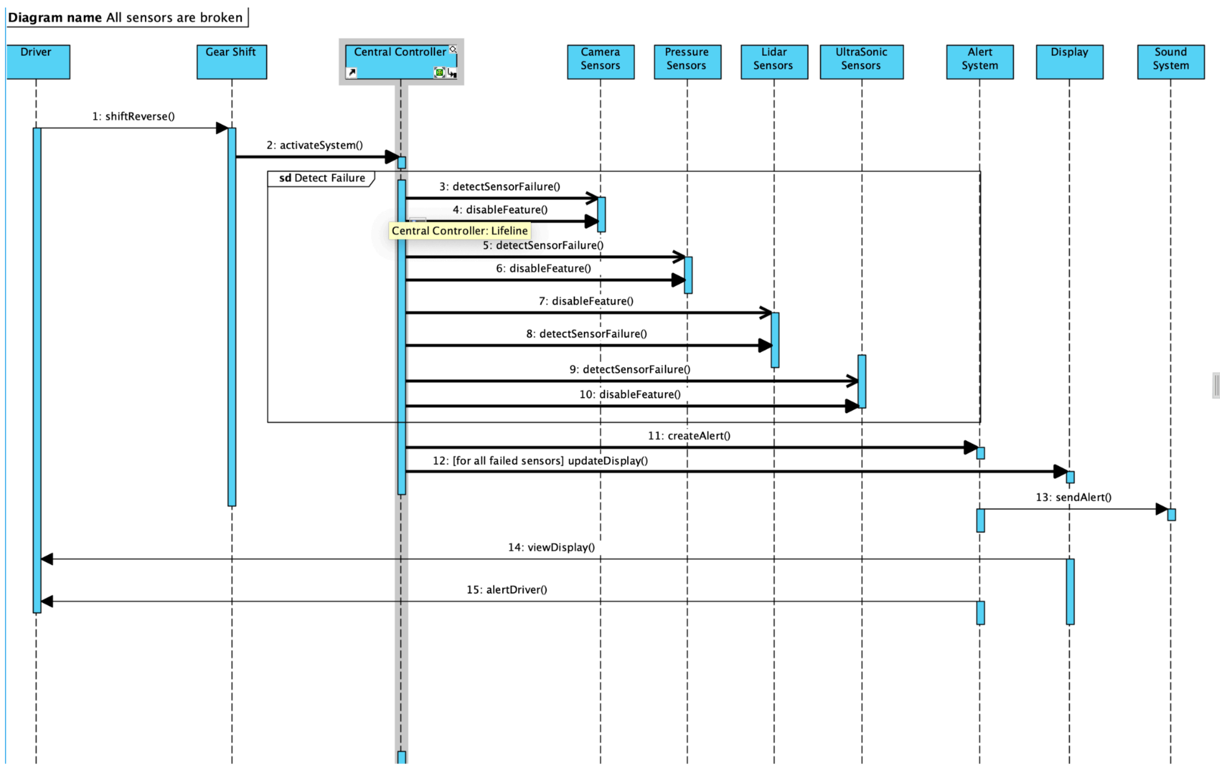

Figure 4.5.6 All sensors are broken

As shown in figure 4.3.7, the driver shifts the car to reverse, the gear shift notifies the central controller to activate. The central controller checks to see if the lidar sensor is broken/failing. If the sensor is found to be broken, the central controller disables its features. It then generates an alert for each broken sensor and updates the display system accordingly. The alert system forwards the notification to the sound system. The driver can then view the alert on the display system. The alert system delivers the sound or vibration alert to the driver.

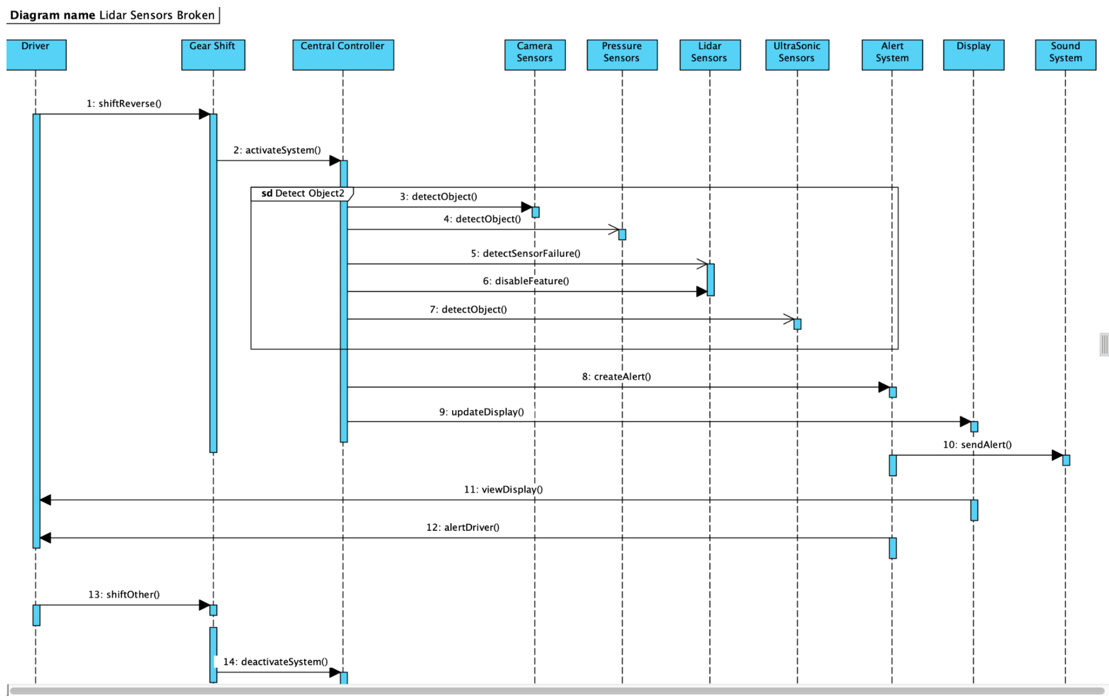

Figure 4.3.7 Lidar Sensor is broken

As shown in figure 4.3.8, the driver shifts the car to reverse, the gear shift notifies the central controller to activate. The central controller checks to see if the camera sensor is broken/failing. If the sensor is found to be broken, the central controller disables its features. It then generates an alert for each broken sensor and updates the display system accordingly. The alert system forwards the notification to the sound system. The driver can then view the alert on the display system. The alert system delivers the sound or vibration alert to the driver.

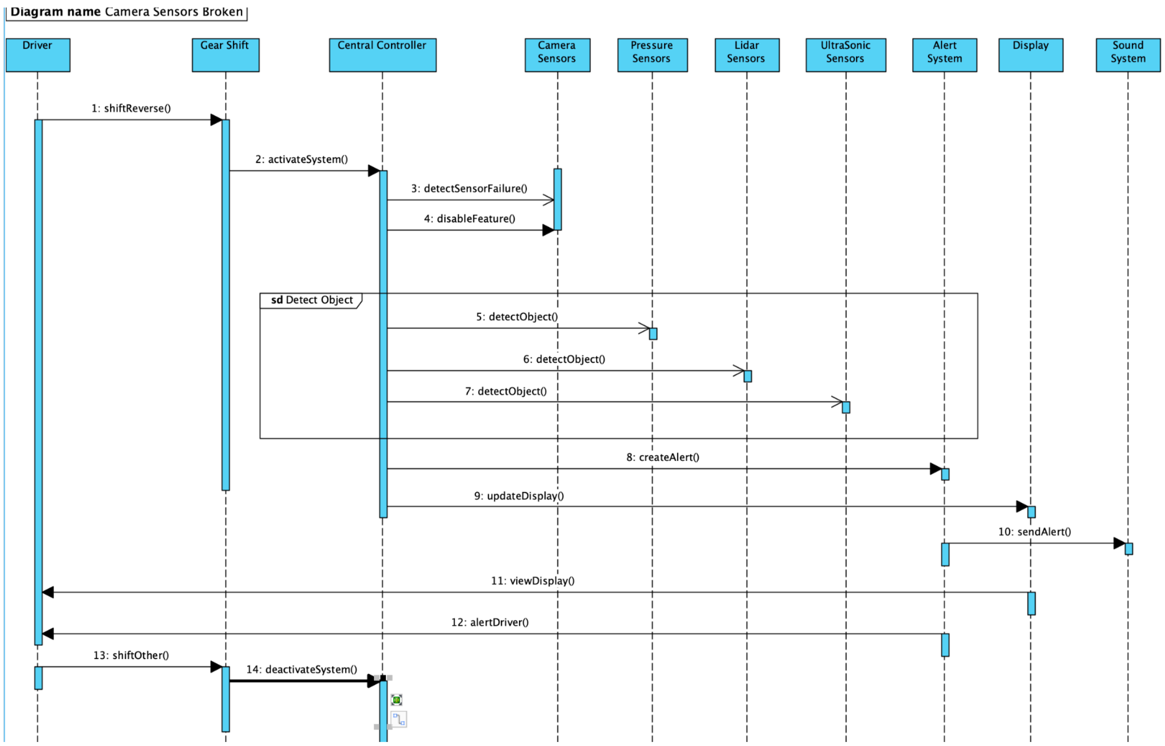

Figure 4.3.8 Camera Sensors are broken

As shown in figure 4.3.9, the driver shifts the car to reverse, the gear shift notifies the central controller to activate. The central controller checks to see if the ultrasonic sensor is broken/failing. If the sensor is found to be broken, the central controller disables its features. It then generates an alert for each broken sensor and updates the display system accordingly. The alert system forwards the notification to the sound system. The driver can then view the alert on the display system. The alert system delivers the sound or vibration alert to the driver.

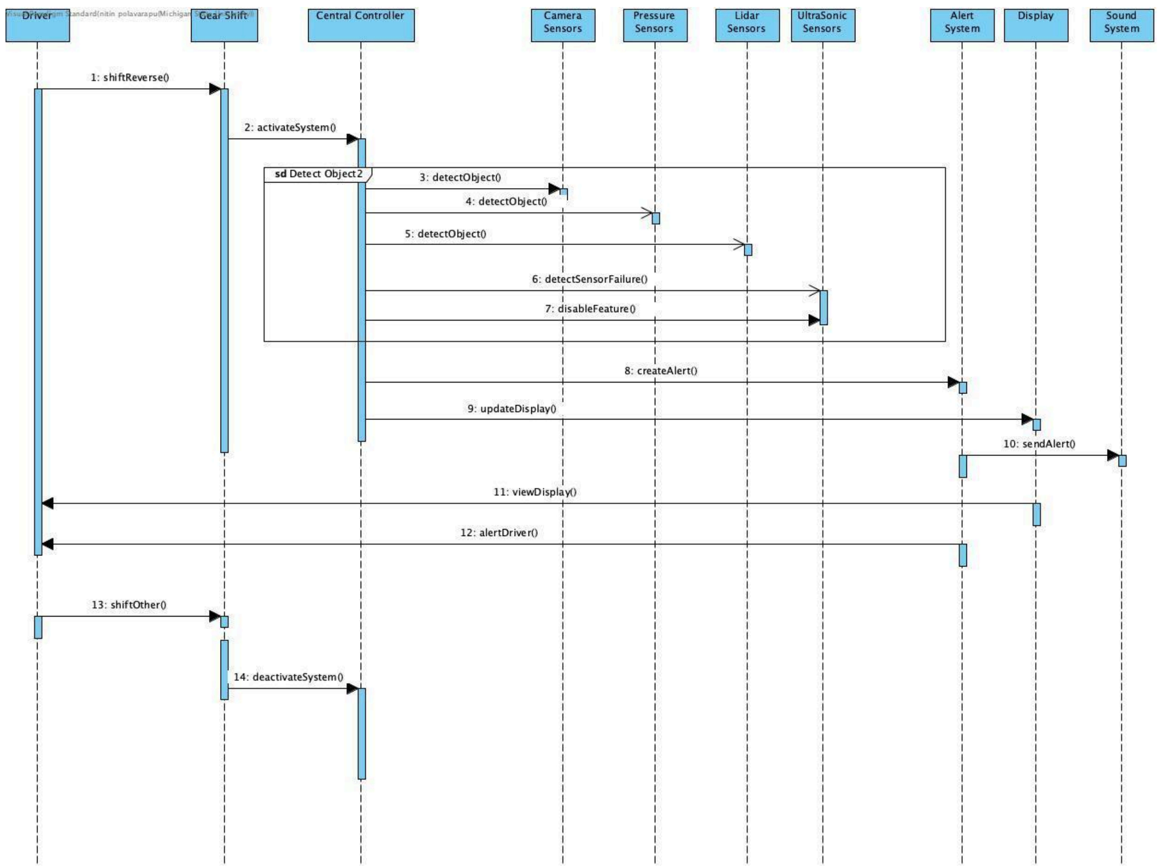

Figure 4.3.9 Ultrasonic sensor is broken

As shown in figure 4.3.10, the driver shifts the car to reverse, the gear shift notifies the central controller to activate. The central controller checks to see if the pressure sensor is broken/failing. If the sensor is found to be broken, the central controller disables its features. It then generates an alert for each broken sensor and updates the display system accordingly. The alert system forwards the notification to the sound system. The driver can then view the alert on the display system. The alert system delivers the sound or vibration alert to the driver.

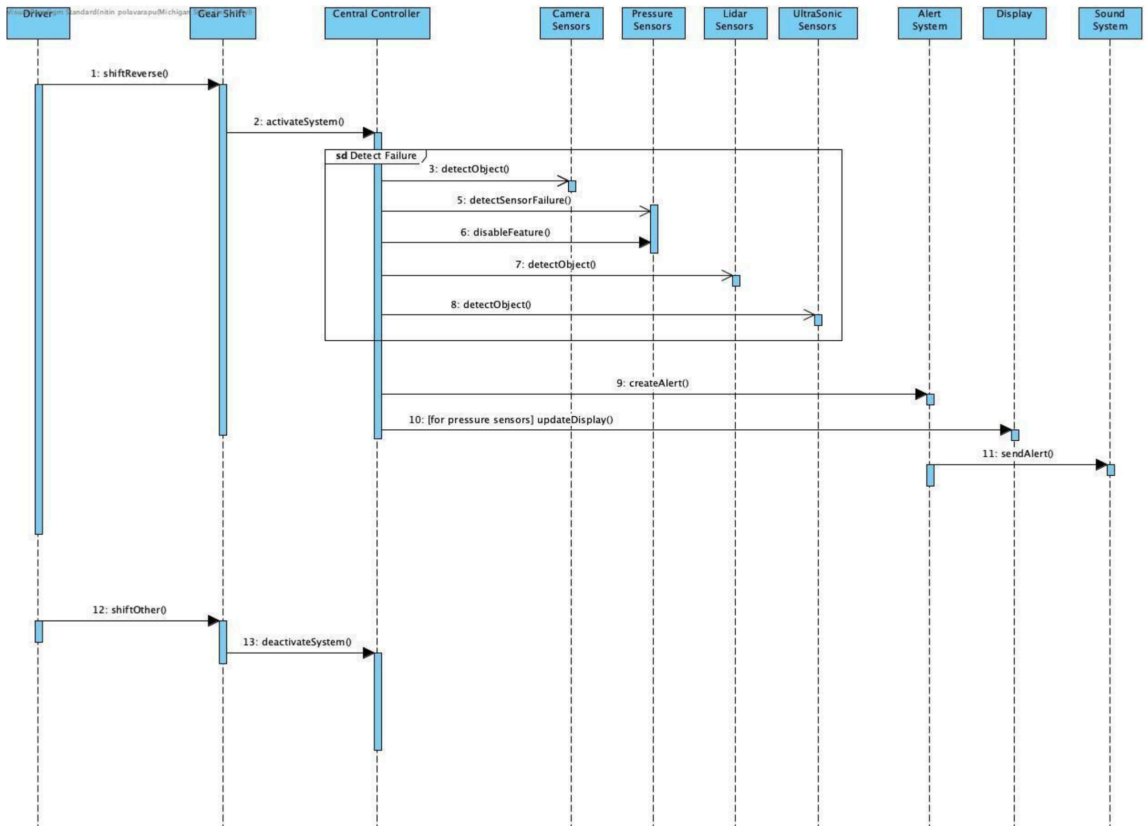

Figure 4.3.10 Pressure sensor is broken

As shown in figure 4.3.11, the driver shifts the car to reverse, the gear shift notifies the central controller to activate. The central controller checks to see if any of the sensors are broken/failed. After checks have been completed see if any object has been detected. If the central controller detects that sensor has detected an object within 3 inches and if so, activate the automatic braking system. Once the automatic braking system is active the drive overrides the system allowing for the car to continue in reverse. Repeats checks for an object until the driver shifts out of gear, sending the deactivated single to the central controller.

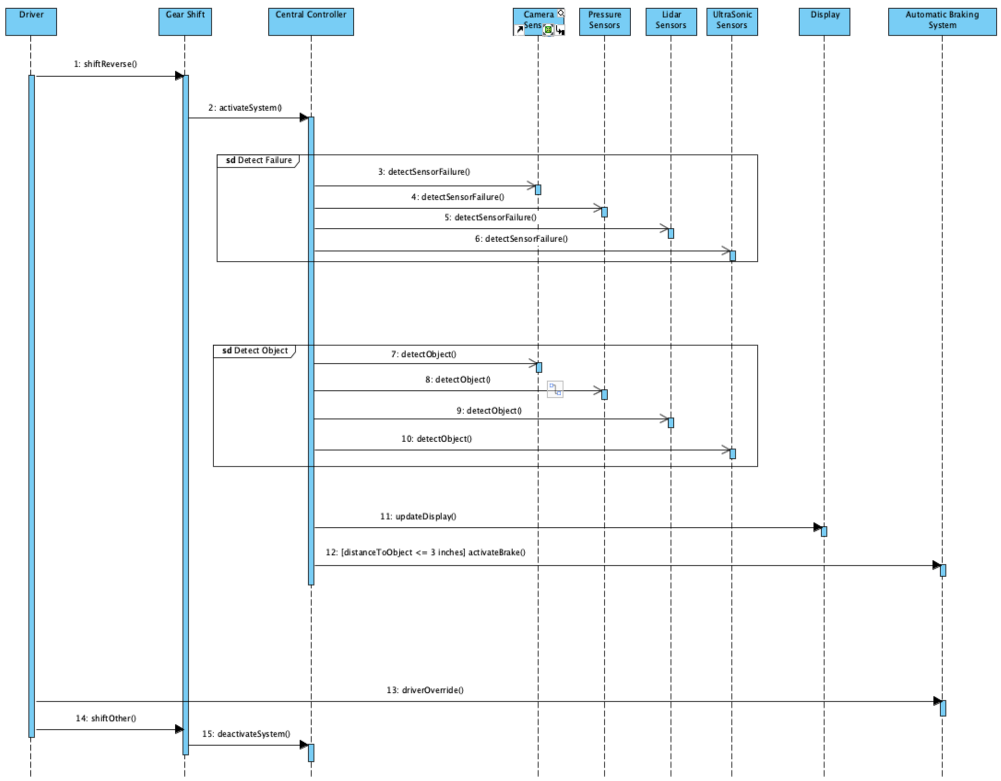

Figure 4.3.11

4.4. State diagram

4.4.1 Driver

Figure 4.4.1 showcases the behavior of the drivers described in our scenario diagrams. Drivers can use the gear shift to shift into or out of the reverse state and this will result in the activation of the system if shifted into reverse or the deactivation of the system if shifted out of reverse. Along with that the driver can interact with a brake by pressing on it which will transition it to the brake on state and result in overriding automatic braking.

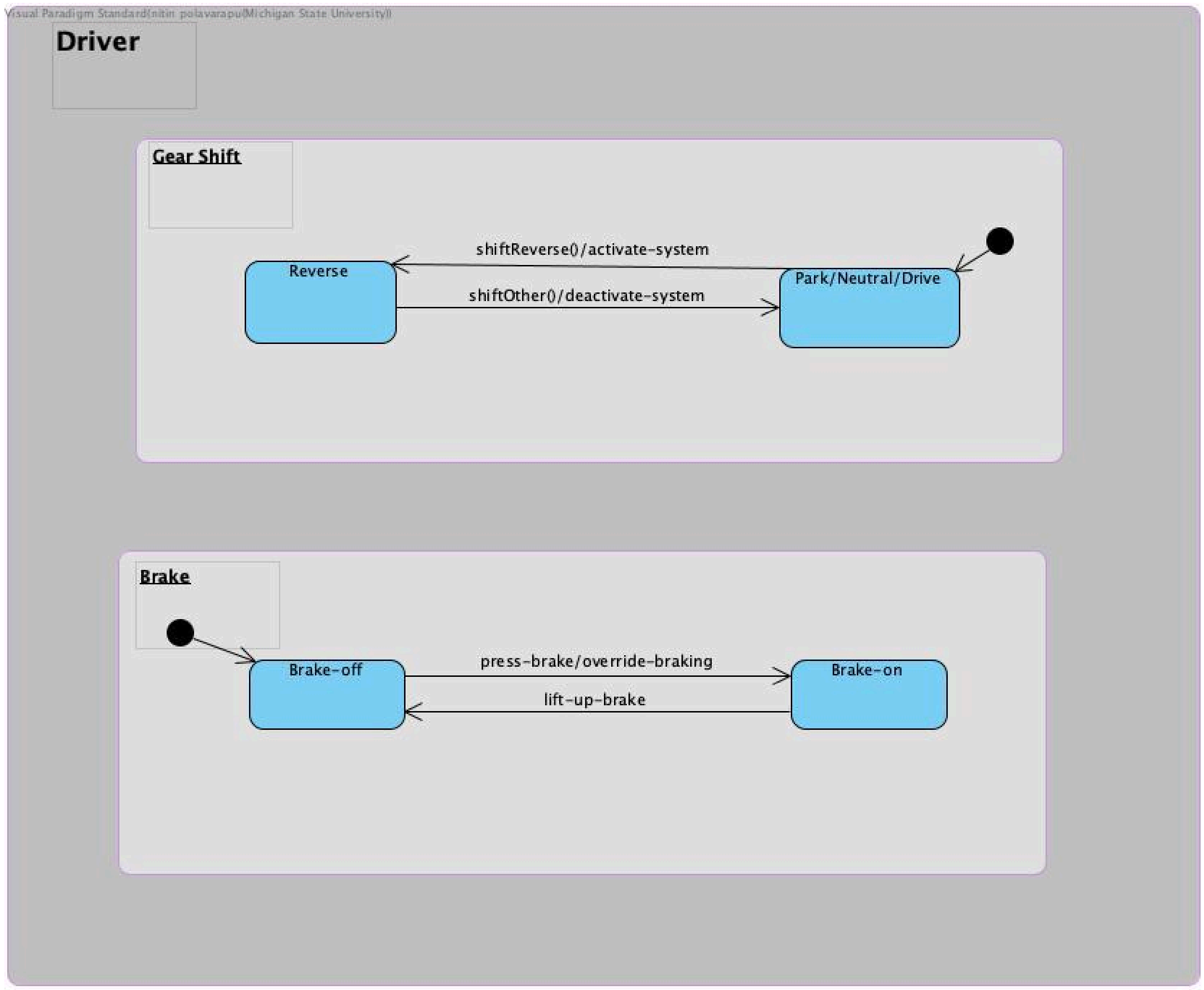

Figure 4.4.1 Driver

4.4.2 Gear Shift

Figure 4.4.2 showcases the behavior of the gear shift in our scenario diagram. The gear shift has two states with one being the park/drive/neutral state and the reverse state. When transitioning to the reverse state, the system will be activated and when transitioning out of reverse the system will be deactivated.

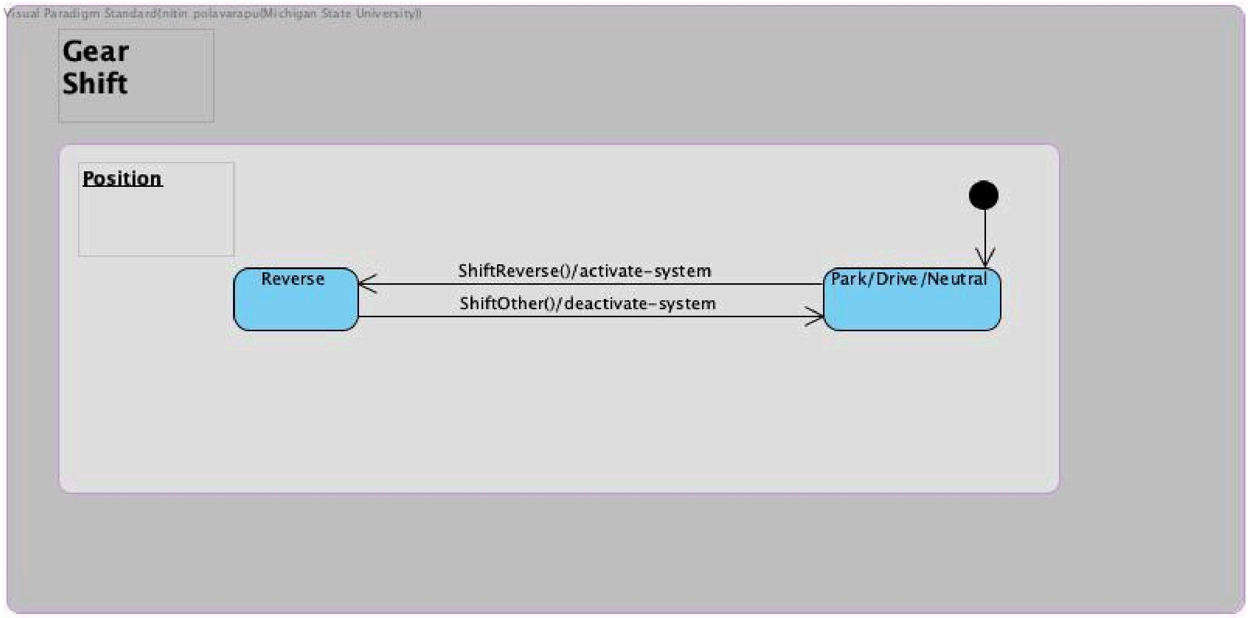

Figure 4.4.2 Gear Shift

4.4.3 Display

Figure 4.4.3 demonstrates how the display works in the scenario diagrams. The camera gets active and the driver puts the car into reverse. Once the cameras is activated it will refresh the camera every .0167 seconds until the driver take the car out of reverse.

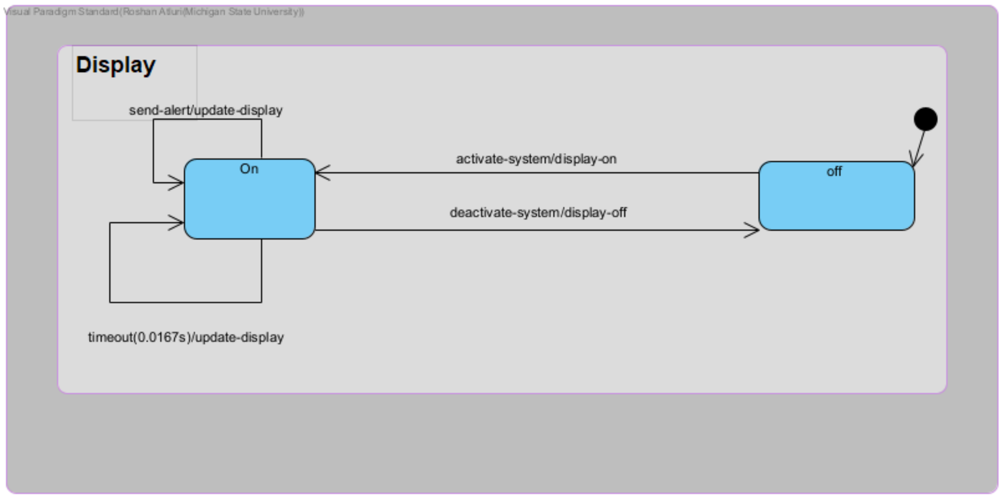

Figure 4.4.3 Display

4.4.4 Camera Sensor

Figure 4.4.4 showcases the behavior of the camera sensor shown in the scenario diagrams. The camera sensor has two states which are an on state and off state. When the camera is activated it transitions from the off state into the on state and when the camera is deactivated it goes from the on state to off state.

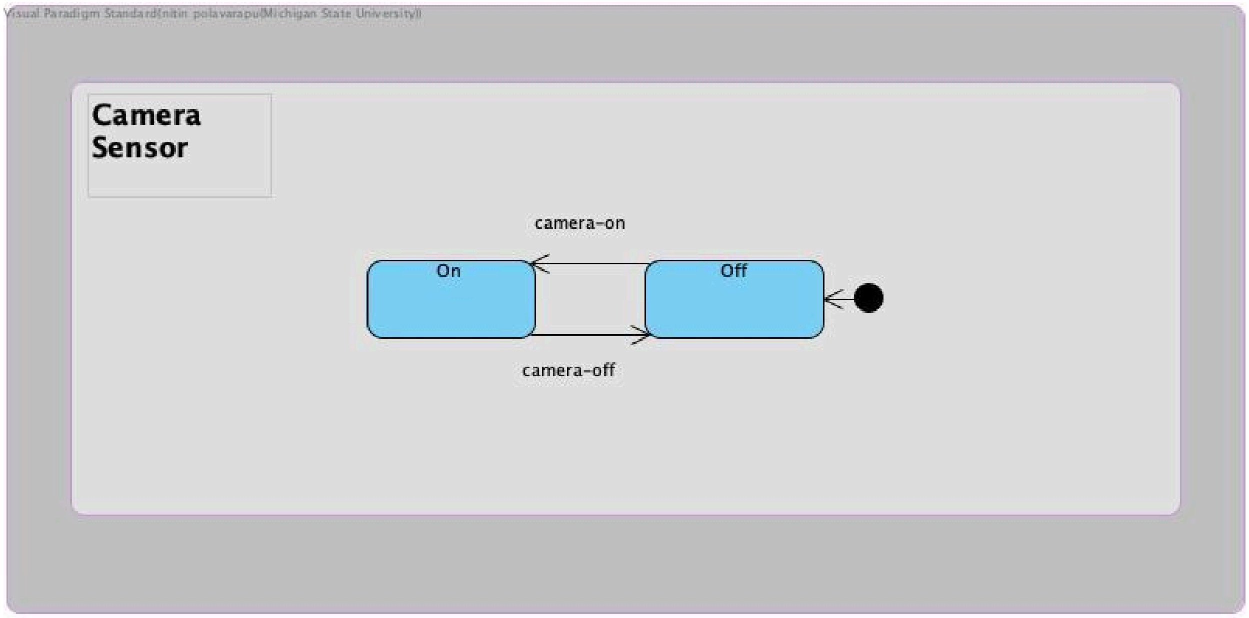

Figure 4.4.4 Camera Sensor

4.4.5 Lidar Sensor

Figure 4.4.5 showcases the behavior of the camera sensor shown in the scenario diagrams. The lidar sensor has two states which are an on state and off state. When the lidar sensor is activated it transitions from the off state into the on state and when the lidar sensor is deactivated it goes from the on state to off state.

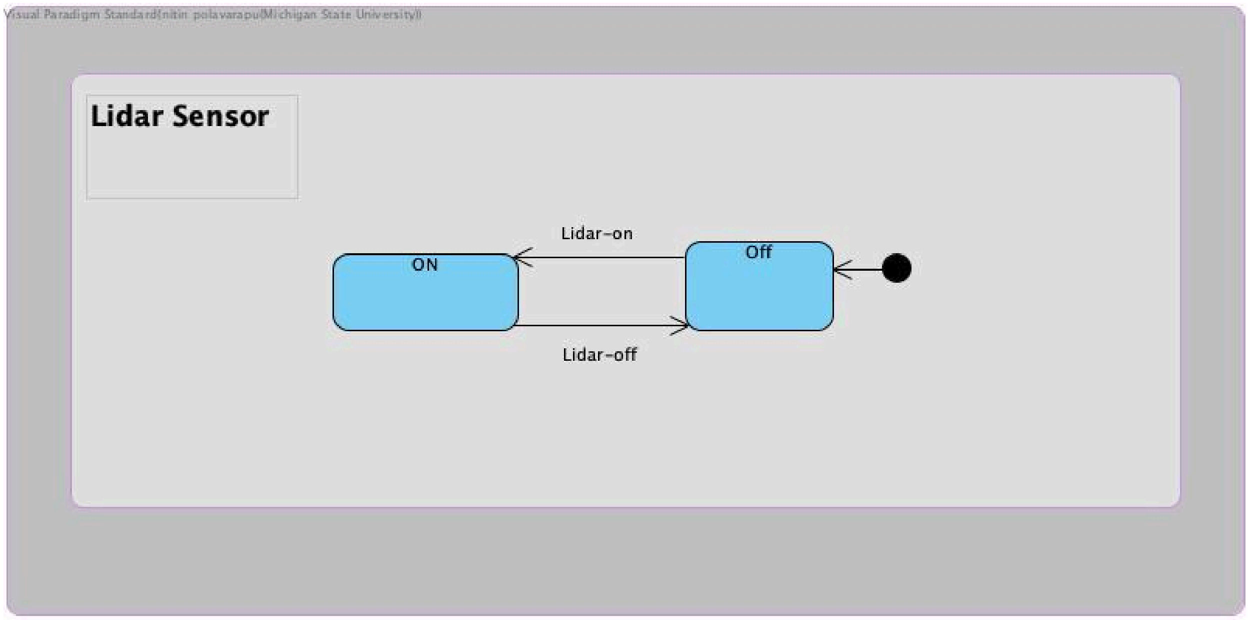

Figure 4.4.5 Lidar Sensor

4.4.6 Pressure Sensor

Figure 4.4.6 showcases the behavior of the camera sensor shown in the scenario diagrams. The lidar sensor has two states which are an on state and off state. When the lidar sensor is activated it transitions from the off state into the on state and when the lidar sensor is deactivated it goes from the on state to off state.

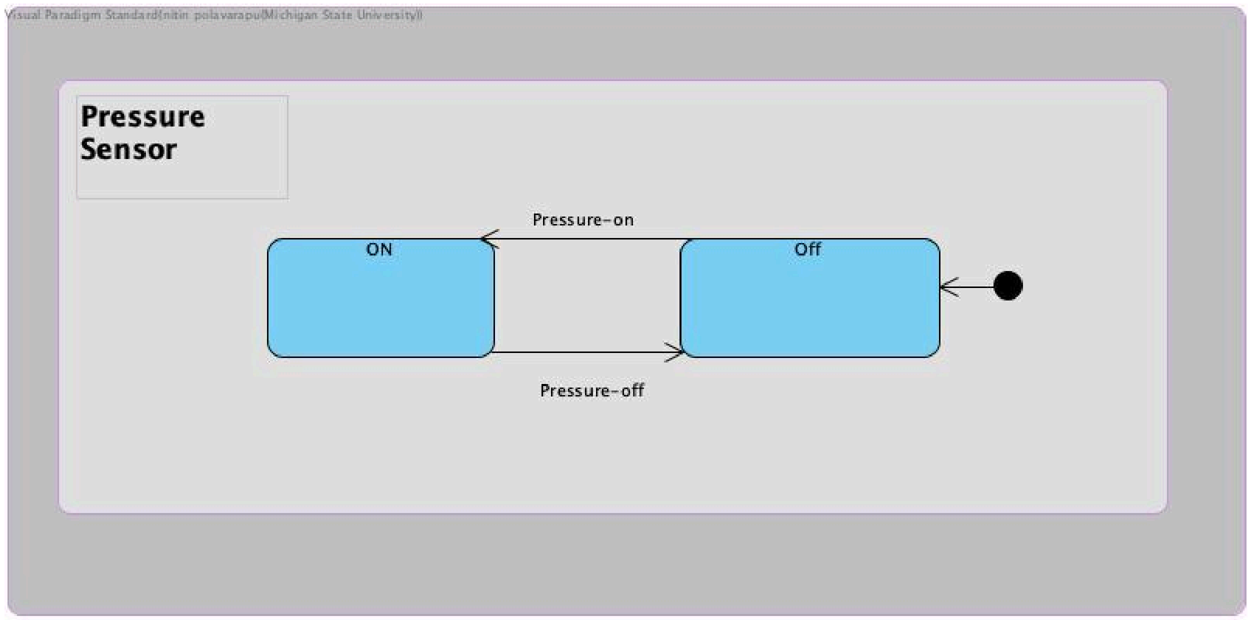

Figure 4.4.6 Pressure Sensor

4.4.7 Alert System

Figure 4.4.7 showcases the behavior of the Alert System in the scenario diagrams. The alert system has four main states starting off with the system initial off. Once the system turns on it awaits for it to be called by the central computer. Then notifies the sound and highlight object onto the screen.

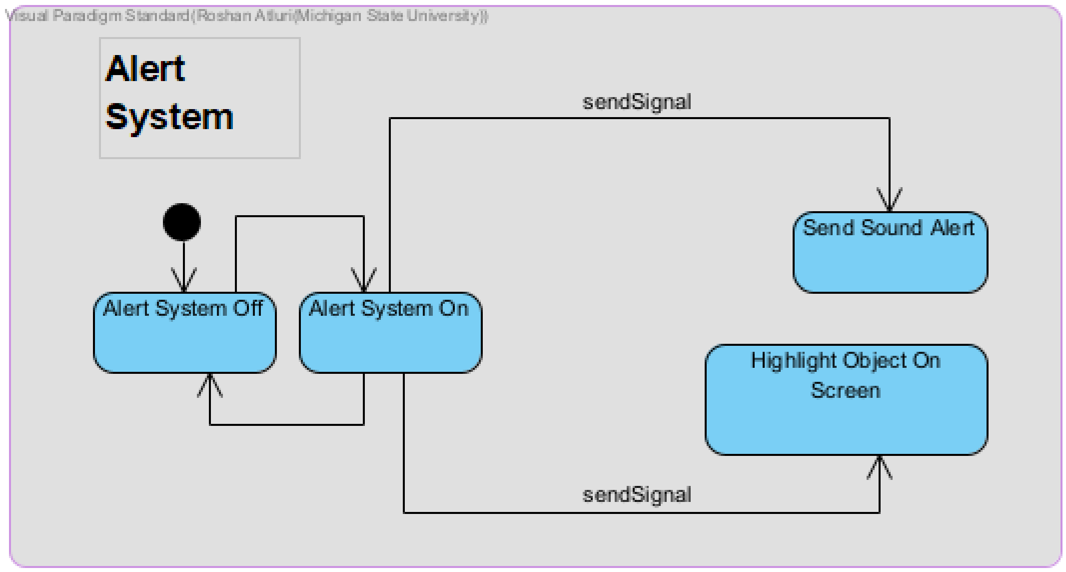

Figure 4.4.7 Alert System

4.4.8 Automatic Braking System

Figure 4.4.8 illustrates the Automatic Braking System in the scenario diagrams. The system is controlled by the central controller, which activates and deactivates it as needed. The Automatic Braking System engages when an alert is triggered within a 3 inch range and disengages when the driver overrides the system.

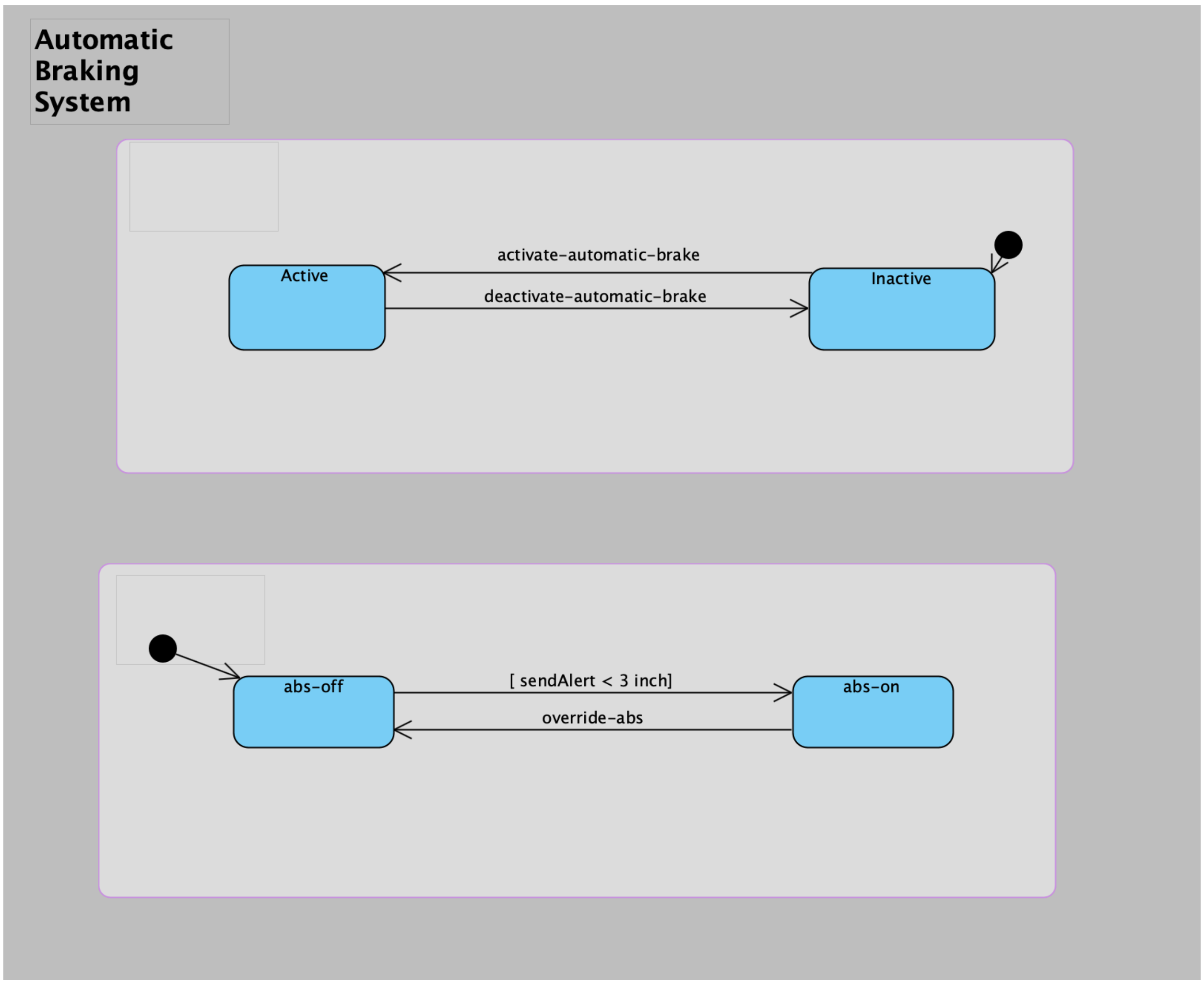

Figure 4.4.8 Automatic Braking System

4.4.9 Central Computer

Figure 4.4.9 showcases the behavior of the central computer as shown in the scenario diagrams. The Central computer has two states which are on and off. When the central computer is shifted into the on position, it is able to detect sensor failure and disable those sensors. If an object is detected the central computer will send a signal to the alert system to alert the driver. And if a crash is detected, the central computer will log the crash. If the central computer detects that all of the sensors are broken it will deactivate the entire system.

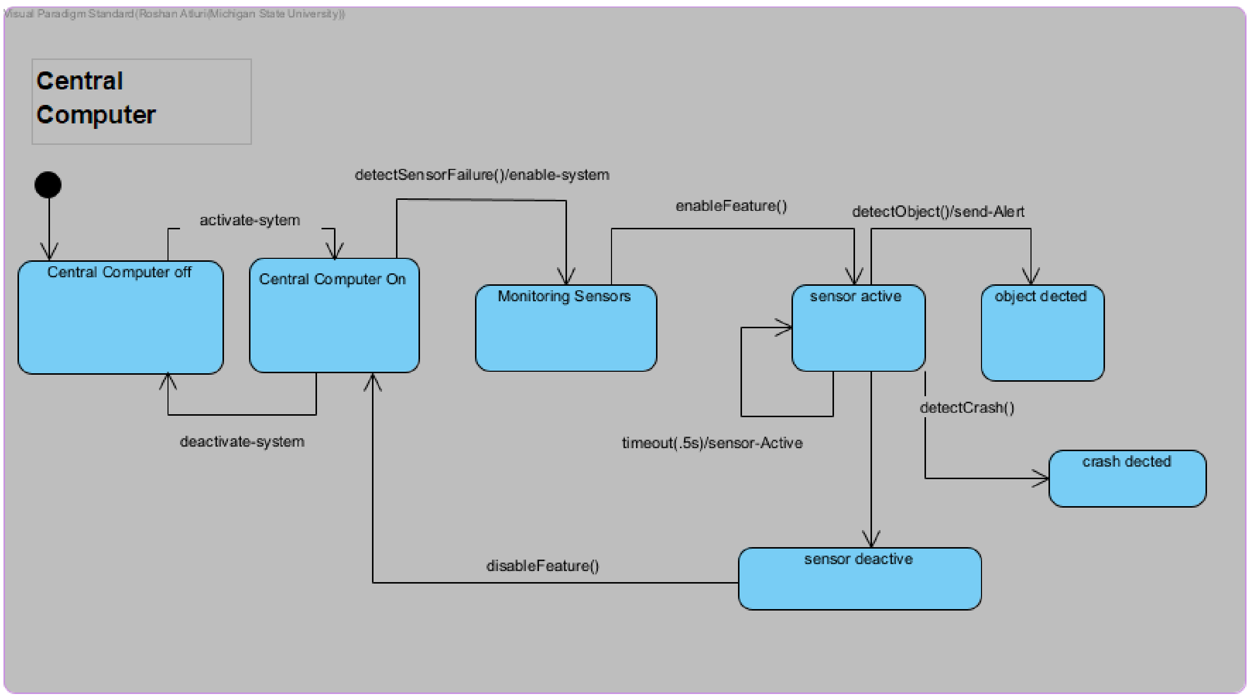

Figure 4.4.9 Central Computer

4.4.10 Sound System

Figure 4.4.10 showcases the behavior of the sound system shown in the scenario diagrams. The sound system has two states which are an alert-off state and alert-on state. When a sendAlert() occurs, the sound system transitions to an alert-on state and after 10 seconds it goes back to the alert-off state.

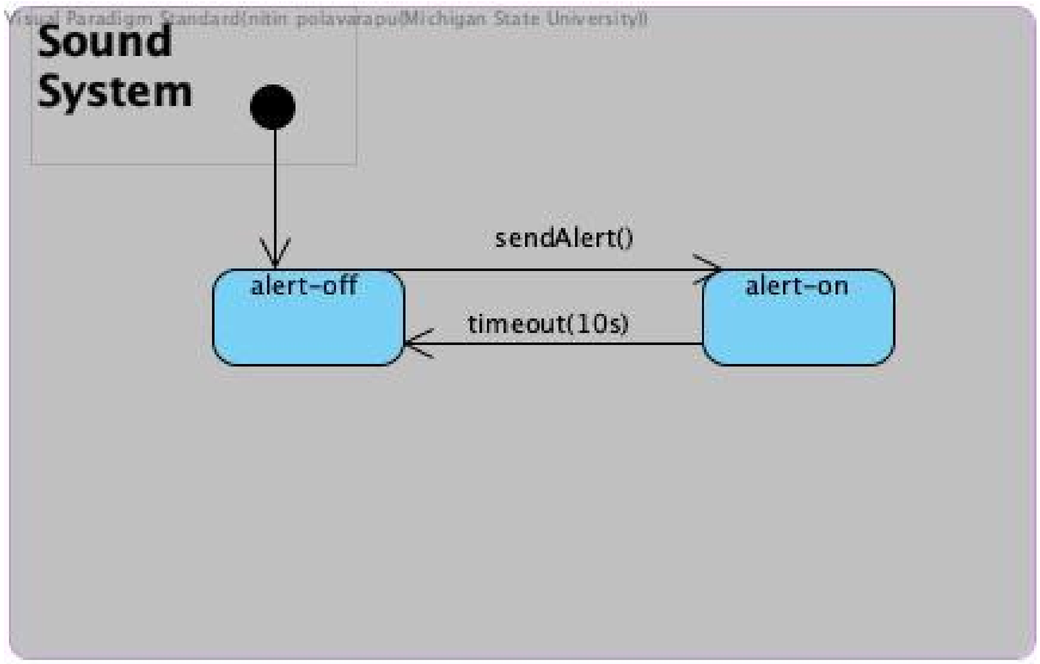

Figure 4.4.10 Sound system

4.4.11 Ultrasonic Sensor

Figure 4.4.11 showcases the behavior of the Ultrasonic sensor shown in the scenario diagrams. The Ultrasonic sensor has two states which are an on state and off state. When the Ultrasonic sensor is activated it transitions from the off state into the on state and when the lidar ultrasonic is deactivated it goes from the on state to off state.

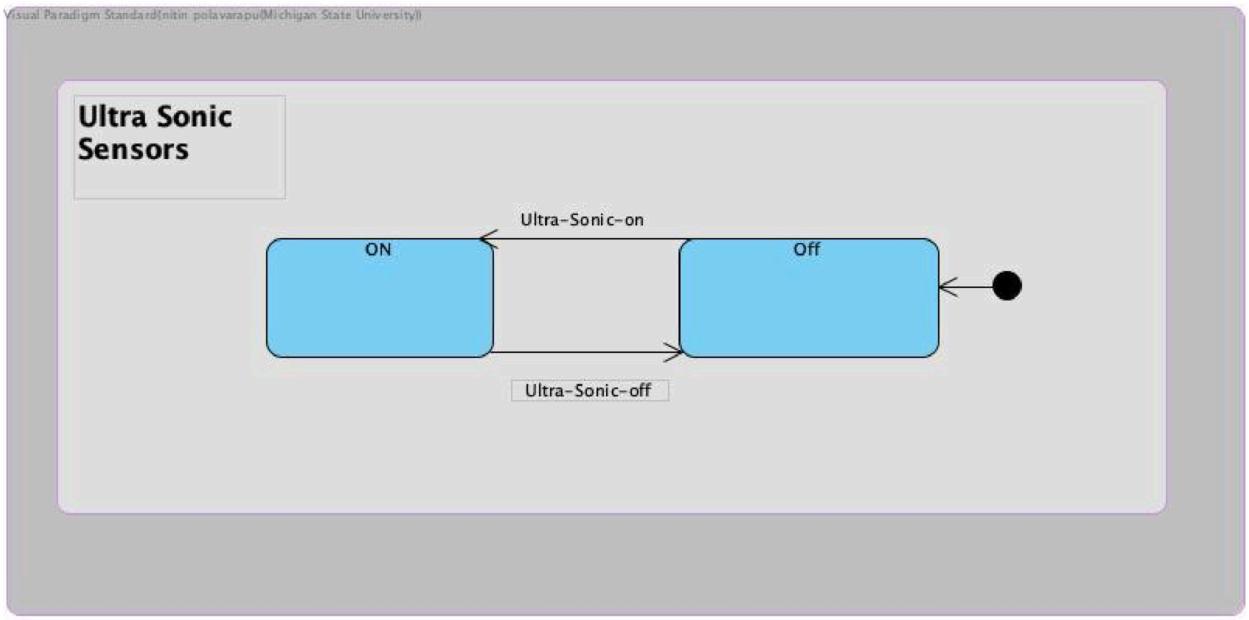

Figure 4.4.11 Ultrasonic Sensor

5 Prototype

- To be added

5.1 How to Run Prototype

- To be added

5.2 Sample Scenarios

- To be added

6 References

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7 Point of Contact

For further information regarding this document and project, please contact **Prof. Betty H.C. Cheng** at Michigan State University (chengb at msu.edu). All materials in this document have been sanitized for proprietary data. The students and the instructor gratefully acknowledge the participation of our industrial collaborators.