Software Requirements Specification (SRS)

Hands-Free Driving System 3

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1 Introduction

The Hands-Free Driving System is an embedded software system inside a vehicle that controls the tasks the user would normally handle such as steering the vehicle, accelerating and braking the vehicle. The Hands-Free Driving System (HFDS) description of requirements is split between the following sections, Overall Description, Specific Requirements, Modeling Requirements, and Prototype. The overall description describes information regarding constraints of the user, system, software and hardware as well as how the system will be used in context of Hands-Free Driving. The specific requirements for the HFDS list what is and is not possible for the system to achieve as well as some cybersecurity requirements for the system. The modeling requirements are a low level display of how the system conveys the requirements. The prototype demonstrates the system in action.

1.1 Purpose

The Software Requirements Specification document serves the purpose of guiding one through the entirety of the Hands-Free Driving System (HFDS) and all of its enabling subsystem. This document is intended to familiarize anyone unfamiliar with the system to understand how the HFDS works and to add further clarity on how to use the system.

1.2 Scope

Software products to be produced to create this HFDS involve the creation of:

- Hands-Free Driving System
    - This is the name of the overall system that encompasses all the subsystems that control the actual HFDS. This system is intended to allow the driver to operate the vehicle hands-free while driving on the highway. The system can be activated on and off by button, as well as relieving temporary control to the driver while the system is activated by accelerating, braking, or steering the vehicle.
    - The system will also ensure the vehicle stays inside it's lane and transitions between HFDS and Hands-On Driving in a safe and convenient manner.
- Driver Assist System
    - A subsystem used to survey necessary information to determine safe conditions for the vehicle. This subsystem manages all of the sensors to ensure proper functioning of the subsystem before sending information to other subsystems to do the functions of HFDS.
    - The subsystem will ensure safe traveling distance between cars in its own lane but will not manage cars in lanes surrounding the vehicle, unless the vehicle merges into the same lane as the vehicle.
- Driver Attention System
    - A subsystem used to monitor the attentiveness of the driver by tracking their head positions and eye position.
    - This subsystem will ensure that the driver is focused on the road (i.e., not distracted) and ready to take back the wheel if the HFDS requires manual control from the driver.
- Vehicle Control System
    - A subsystem used to control the accelerator, braking and steering of the car from commands given by the Driver Assist System.
    - This subsystem controls the main function of the vehicle but will not control the path taken by the vehicle.

- Vehicle Position Subsystem
    - A subsystem used to process the sensor data sent from the Driver Assist System, and identifies the vehicle's position relative to GPS and the lane.
    - This subsystem is used to ensure to the HFDS that the vehicle is in an acceptable condition to continue to use the HFDS feature.
- Path Prediction Subsystem
    - A subsystem used to calculate the cars projected path on the highway based on information processed by the Vehicle Position Subsystem compared to LiDAR mappings pre-installed in the car or by over-the-air update.
    - The subsystem will create the path for the vehicle. It will not command the vehicle to follow the path; the path will be used by the HFDS and the Vehicle Control System.
- Human Machine Interface Subsystem
    - The subsystem will communicate to the driver when the HFDS is ready to be activated, in-use, has imminent warnings and when it needs the driver to return control of the vehicle.

1.3 Definitions, acronyms, and abbreviations

<u>Hands-Free Driving System (HFDS)</u> - A subsystem that allows the vehicle to automatically steer, accelerate, and brake in certain highway conditions. Allows the driver to remove hands from the steering wheel and issues warnings if the driver is deemed distracted or if the system needs the driver to retake control [1].

<u>Driver Assist System</u> - A subsystem that polls necessary information to determine safe conditions, vehicle position and current trajectory. Ensures safe following distance. Issues commands to the Vehicle Control System [1].

<u>Driver Attention System</u> - A subsystem that uses cameras to monitor drivers head position and eye location to ensure active engagement between driver and the road. If the subsystem detects lack of engagement, warnings are issued to alert drivers to re-engage [1].

<u>Vehicle Control System</u> - A subsystem that controls the braking, accelerating, and wheel input of the car from instructions given by the Driver Assist System [1].

<u>Vehicle Position Subsystem</u> - A subsystem that processes the various sensors data and validates vehicle position [1].

Path Prediction Subsystem - A subsystem that calculates the cars projected path based on information from the Vehicle Position Subsystem and LiDAR mappings [1].

Human Machine Interface Subsystem (HMIS) - A subsystem that accepts input from the driver, communicates back and forth between the driver and the HFDS, displays sensor information [1].

Safe - Protected from or not exposed to danger or risk; not likely to be harmed [2].

Light Detection and Ranging (LiDAR) - A remote sensing method that uses light in the form of pulsed laser to measure ranges [3].

Global Positioning System (GPS) - An accurate worldwide navigation and surveying facility based on the reception of signals from an array of orbiting satellites [4].

WebGL – A Javascript API for rendering high-performance interactive 3D and 2D graphics within any compatible web browser without the use of plug-ins [5].

Infrared Camera - A device that creates an image using infrared radiation similar to how a common camera forms images using visible light [6].

Adaptive Cruise Control - Intelligent form of cruise control that automatically speeds up and slows down the vehicle to keep pace with the cars in front and behind you [7].

Radar - A system for detecting the presence, direction, distance and speed of objects by sending out pulses of high frequency electromagnetic waves that are reflected off the object and back to the source [8].

Unity - Development software often used to create games and other interactive media.

Blue Path - A path used to guide the vehicle along its trajectory safely created by the Path Prediction Subsystem.

1.4 Organization

Section 1 describes the components of the system, their scope in terms of how they are used at a high level, definitions of many useful terms used throughout the document, as well as the organization of the rest of the document. Section 2 provides descriptions of the HFDS framework, along with its constraints of the interfaces and user expectations or characteristics, the descriptions of all the functions, description of the states the system flows through, and the features that are beyond the scope of the system. Section 3 goes through the specifications and requirements of the system. Section 4 provides graphical models to illustrate the software components, use cases, domain, sequence and state for the HFDS. Section 5 introduces a prototype for the HFDS, describes how to use the prototype, as well as a sample scenario to show how the system works. Section 6 gives the references for the SRS. Section 7 gives information on who to contact for further information.

2 Overall Description

The information that will be covered in this section is the context of the HFDS. Section 2.1 covers constraints of the system, including those of the software, hardware, and user. Section 2.2 covers the description of the functions. This is followed up by Section 2.3 which states the expectations of the user. Section 2.4 covers safety-critical constraints. Section 2.5 states assumptions the system makes. Lastly, in Section 2.6 the features that are beyond the scope of this system are stated.

2.1 Product Perspective

The HFDS should be used on the highway when the driver does not want to manually steer the car with the steering wheel or control the speed. The vehicle maintains the same lane when the HFDS is activated.

There are many system constraints for the HFDS. System constraints include dependencies on pre-existing features like adaptive cruise control or LiDAR. The system also relies on the driver to be paying attention to work. The user interface is constrained by displaying visual warnings on the dash and steering wheel. Also, the user interface has audio cues that can only be heard from the sound system of the car. The final warning to get the driver’s attention is done by vibrating the seat of the car. The hardware constraints include the exterior and interior cameras, the steering wheel of the car, gas and brake pedals. Figure 1 shows the high-level goals of the HFDS.

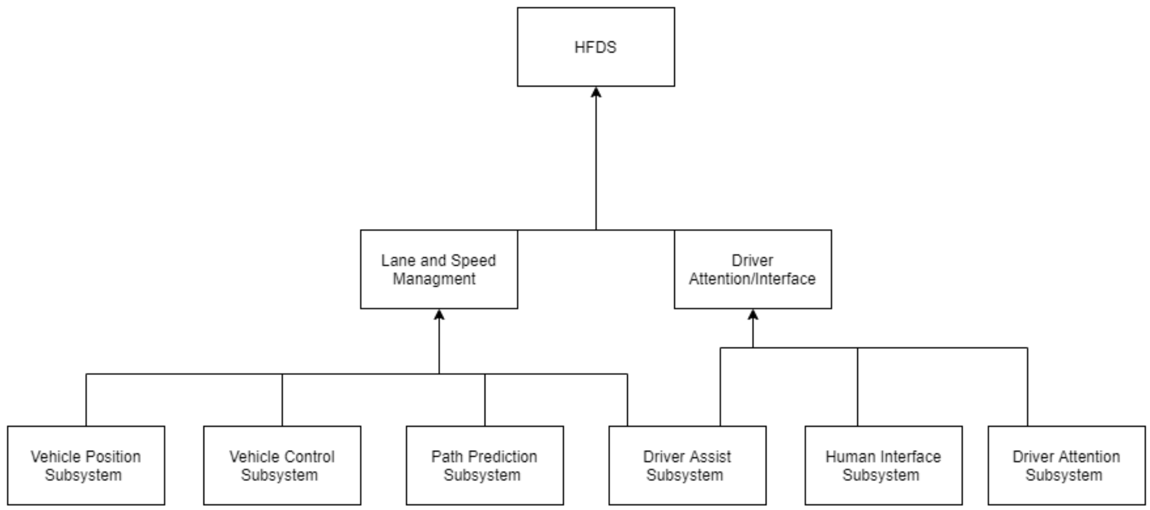

Figure 1: Diagram of the high-level goals of the HFDS

2.2 Product Functions

There are many subsystems for the HFDS which need descriptions to understand the system as a whole. One function of the system is called the Driver Assist Subsystem and it grabs data necessary to determine safe conditions. Also it calculates vehicle position, and trajectory ensuring safe following distance. The Driver Attention Subsystem monitors the eye and head movement of the driver to decide whether or not they are paying attention and warns inattentive drivers. The Vehicle Control System uses the driver assist data to decide whether to turn, brake, or accelerate. Human Machine Interface Subsystem is another subsystem that uses data from other systems to display warnings or issues with the system. Path Prediction Subsystem is a system that uses LiDAR, and GPS mapping to create a path for the vehicle to proceed. The last system is the Vehicle Position System which reads information from exterior cameras to give the hands-free driving system the vehicles real world position.

2.3 User Characteristics

There are a few expectations of the user to operate the system. The user is expected to be capable of operating a vehicle and operates the vehicle legally. The user is expected to have knowledge of the Hands-Free Driving and how to use it.

2.4 Constraints

The HFDS is a safety-critical system because people's lives are at risk, therefore the constraints that come with being a safety-critical system apply here:

1. If any camera turns off or a warning sign is not being displayed properly the system shuts off.
2. The system must have hardware and sensor backups to ensure safety and to give the driver proper time to engage with the steering wheel.
3. The driver must be paying attention at all times. If the driver is not paying attention and the warning signs are ignored, the vehicle will come to a complete stop.

2.5 Assumptions and Dependencies

There are a few assumptions and dependencies that must be known before understanding the HFDS.

1. Lane detection and cruise control are pre-existing features that the HFDS depends on.
2. The mapping of highways for path prediction is also a dependency for the HFDS.
3. The driver is paying attention on the road and aware of their environment is an assumption.
4. The weather is appropriate for driving.
5. The vehicle is on the highway and does not switch lanes at any point is an assumption.
6. The car does not need any maintenance, and all hardware in the system is working properly are both assumptions for the HFDS.
7. The software is communicating properly with itself.

2.6 Apportioning of Requirements

There are a few requirements that are beyond the scope of this project. In the meeting with our customer we discussed changing lanes as a feature beyond the scope of this project. Another point of interest discussed with the customer is that the car will not pull over to the side of the road when the driver is not paying attention. Rather, the HFDS comes to a complete stop in the same lane of the vehicle when the HFDS is activated. Also, using this system on roads other than highways is beyond the scope of this project. Lastly, adapting to an unexpected path (due to construction or another independent variable) is out of the scope for the HFDS.

3 Specific Requirements

The specific requirements for the HFDS as enumerated by the team are below. The requirements are numbered 1 through 16 and C-1 through C-2 for reference throughout the rest of this document. These requirements list both the required behavior of the system as well as constraints and priorities of the system.

1. The Driver Assist System must validate a safe trajectory before activating HFDS by checking:
    1.1. Road conditions including checking for unsafe conditions such as:
        1.1.1. Weather conditions
        1.1.2. Construction zones
        1.1.3. Blocked paths or slow moving vehicles
        1.1.4. Highways that end or turn into roads with lights and intersections
    1.2. Current trajectory
    1.3. Sensor input
    1.4. Predicted path
    1.5. Health of the car (via check engine light)
2. When the HFDS is active, the Driver Attention System monitors driver behavior to ensure active engagement by:
    2.1. Making sure eyes and head are in engaged position
    2.2. Sending warnings until resumed engagement if the driver is inattentive
    2.3. Sending a final warning via vibration if the driver remains inattentive
    2.4. Aborting hands-free mode and if necessary, brings the vehicle to a stop if the driver is inattentive for too long
3. The system must monitor eye and head positions to determine if the driver is active. The eye and head tracking must work in any lighting
4. The system must issue warnings to driver:
    4.1. If the driver is distracted
    4.2. If the system requires driver to take back control, such as in the case of:
        4.2.1. Faults being found in the system
        4.2.2. Inability to determine positions of lane markings
5. The driver can temporarily resume control of vehicle at any time by giving input to any of the following:
    5.1. Steering wheel
    5.2. Brake pedal
    5.3. Accelerator
6. The driver can disable the HFDS by pressing a button
7. If the driver supplies input to the vehicle (steering, accelerating, or braking) while HFDS is active, HFDS will temporarily stop controlling the vehicle while input is supplied

8. HFDS will only activate when requested by the user on highways that have been enabled by the Path Prediction Subsystem
9. HFDS will maintain position within lane through curves in road while active
10. HFDS will maintain either a set speed or the speed of vehicles in front of the car, whichever is less
11. HFDS will maintain redundancy of all sensors and hardware
12. HFDS collect, interpret, and display data about the position, trajectory, and environment of the vehicle using the HMIS
13. HFDS will calculate the best trajectory for the vehicle and control steering to take that path.
14. HFDS should maintain safe distance from all vehicles, construction workers, pedestrians, and wildlife.
15. HFDS will verify the vehicle's position using data from the four sources below. If there is disagreement between input sources, the user will be prompted to take control.
    15.1. LiDAR
    15.2. Cameras
    15.3. Radar
    15.4. GPS
16. The driver can enable the system by pressing a button once adaptive cruise control is already enabled

3.1 Cybersecurity Requirements

Requirements related to cybersecurity have been separately enumerated for clarity. These cybersecurity requirements specifically pertain to the confidentiality, integrity, and/or availability of the system and the data within. These requirements are denoted C-1 through C-2 through the rest of the document.

- C-1. Ensure that sensors and cameras are genuine from the factory, prevent enabling system if non-genuine parts are detected
- C-2. Defend against unauthorized modifications to the system

4 Modeling Requirements

This section includes UML models describing the possible uses of the system in a use case diagram, the elements of the system in a domain model, the sequence events during operation of the system in sequence diagrams, and the possible states of the system in a state diagram. A data dictionary is provided to provide further detail on the domain model, and use case descriptions are provided to provide clarification on the use case diagram.

4.1 Use Cases

Figure 2 is a use case model which its primary goal is to display how the system conveys the requirements of the customer. In the use case model, the system has 9 actors (driver, interior camera, exterior camera, adaptive cruise control, LiDAR, radar and GPS, steering wheel, audio system, brakes, and gas). These actors interact with the six subsystems (Driver Assist, Human Interface, Vehicle Control, Path Prediction, Driver Attention, and Vehicle Position). These subsystems are what allows the HFDS to function.

Figure 2 illustrates the functionality of the Hands-Free Driving system along with the different use cases including driver inattentiveness, the driver manually enabling and disabling the system, and checking for safe conditions for the system to enter Hands-Free Driving. For the cross references, when a top-level requirement is listed for each Use Case, it also covers all lower levels.

Figure 2 is a UML use case diagram. In the diagram, stick figures represent actors, which are elements outside of the system that interact with or are interacted with by the system. The large rectangle represents the system boundary; everything within that rectangle represents the functionality of our system, and everything outside of it is not part of the system, but interactions with the environment is part of the system. The ellipses within the system boundary are use cases of the system, and represent the functionalities that the system must support. The interior rectangles represent internal system boundaries of each subsystem of the larger system. The lines between the actors and use cases represent interactions between use cases and actors; either actors performing actions on the system or the system interacting with the actors. Lines between use cases are marked using either “<<extends>>” or “<<includes>>” depending on the interaction between the use cases. If one use case requires separate functionality then it must “include” another use case. On the other hand, if a use case is a special case of a different one then it must “extend” that use case.

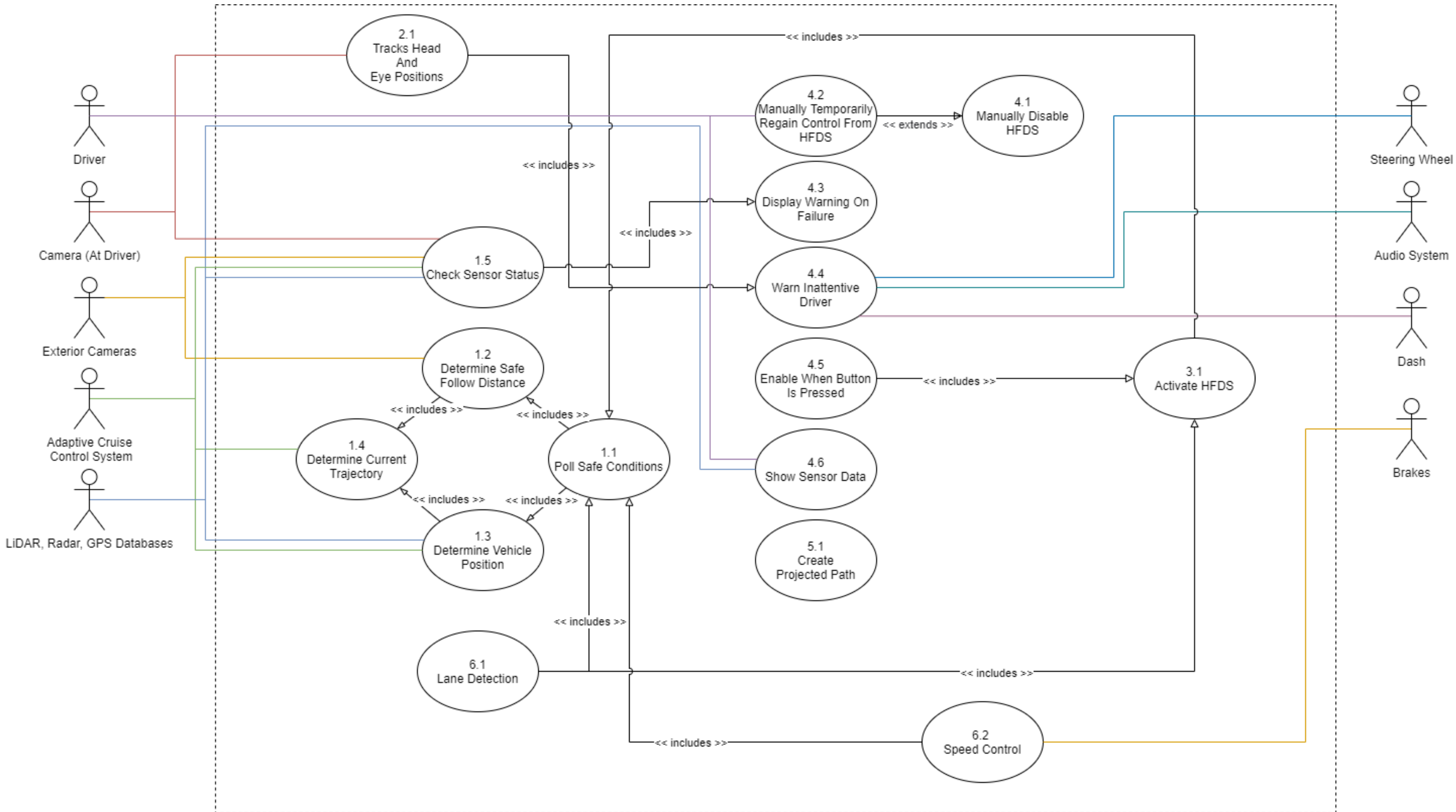

Figure 2: Use case diagram for HFDS and its use cases for each subsystem

The following tables are use case descriptions that further explain the use cases shown in Figure 2.

Number:	1.1
Use Case:	Poll Safe Conditions
Actors:	N/A
Description:	Polls necessary data to determine safe conditions
Type:	Primary and essential
Includes:	1.2, 1.3
Extends:	N/A
Cross-refs:	1
Use cases:	3.1, 6.1, 6.2

Number:	1.2
Use Case:	Determine Safe Follow Distance
Actors:	Adaptive Cruise Control
Description:	Calculates the distance to the vehicle or object in the path of the vehicle and uses relative velocities of the vehicles to determine safe following distances.
Type:	Primary and essential
Includes:	1.4
Extends:	N/A
Cross-refs:	1, 10
Use cases:	1.1

Number:	1.3
Use Case:	Determine Vehicle Position
Actors:	Exterior Cameras, LiDAR and GPS Databases
Description:	Determines the vehicle’s position relative to pre-mapped location data cross referencing camera inputs and positional databases. Also determines position within a lane using camera inputs.
Type:	Primary and essential
Includes:	1.4
Extends:	N/A
Cross-refs:	1, 3, 8, 9, 12, 16
Use cases:	1.1

Number:	1.4
Use Case:	Determine Current Trajectory
Actors:	Adaptive Cruise Control
Description:	Obtains the vehicle’s current trajectory and speed
Type:	Primary and essential
Includes:	N/A
Extends:	N/A
Cross-refs:	1, 10, 12
Use cases:	1.2, 1.3

Number:	1.5
Use Case:	Check Sensor Status
Actors:	Internal Camera, External Cameras, LiDAR and GPS Databases, Adaptive Cruise Control
Description:	Ensures sensors are working properly.
Type:	Secondary and essential
Includes:	N/A
Extends:	N/A
Cross-refs:	1.3, 11, C-1, C-2
Use cases:	4.3

Number:	2.1
Use Case:	Track Head And Eye Position
Actors:	Camera (At Driver)
Description:	Camera tracks head and eye position to calculate and ensure the driver is attentive with the road and sends flags to the Human Machine Interface.
Type:	Primary and essential
Includes:	4.4
Extends:	N/A
Cross-refs:	2
Use cases:	N/A

Number:	3.1
Use Case:	Activate HFDS
Actors:	N/A
Description:	Perform the actions necessary to perform hands-free driving based on input received from Driver Assist System.
Type:	Primary and essential
Includes:	1.1
Extends:	N/A
Cross-refs:	15
Use cases:	4.5, 6.1

Number:	4.1
Use Case:	Manually Disable HFDS
Actors:	Driver
Description:	Allow the driver to manually disable the hands-free driving system by pressing a button.
Type:	Primary and essential
Includes:	N/A
Extends:	N/A
Cross-refs:	6
Use cases:	4.2

Number:	4.2
Use Case:	Manually Temporarily Regain Control From HFDS
Actors:	Driver
Description:	Allow the driver to temporarily adjust the heading or speed of the vehicle by moving the steering wheel or pressing on the brake and/or gas, reactivate HFDS control when pedals and wheel are no longer being used by the driver.
Type:	Primary and essential
Includes:	N/A
Extends:	4.1
Cross-refs:	5
Use cases:	N/A

Number:	4.3
Use Case:	Display Warning On Failure
Actors:	N/A
Description:	When a sensor fails, show a warning to the driver on the dash.
Type:	Secondary and essential
Includes:	N/A
Extends:	N/A
Cross-refs:	4.2
Use cases:	N/A

Number:	4.4
Use Case:	Warn Inattentive Driver
Actors:	Audio System, Steering Wheel, Dash
Description:	When the HMIS receives a signal from the Driver Attention System, show warnings and play audio cues corresponding with the level of the warning.
Type:	Secondary and essential
Includes:	N/A
Extends:	N/A
Cross-refs:	4.1
Use cases:	2.1

Number:	4.5
Use Case:	Enable When Button Is Pressed
Actors:	Driver
Description:	When the driver presses the button to enable the HFDS, send a signal to the six other subsystems to engage.
Type:	Primary and essential
Includes:	3.1
Extends:	N/A
Cross-refs:	15
Use cases:	9

Number:	4.6
Use Case:	Show Sensor Data
Actors:	Sensors, Dash
Description:	LiDAR, Radar, GPS Databases obtaining the necessary sensor to display user-friendly information on the dash.
Type:	Secondary and essential
Includes:	N/A
Extends:	N/A
Cross-refs:	12
Use cases:	N/A

Number:	5.1
Use Case:	Create Projected Path
Actors:	LiDAR, Radar and GPS databases
Description:	Retrieves input from Vehicle Position subsystem, interprets information, and compares LiDAR, Radar and GPS databases to determine the blue path for the vehicle to follow.
Type:	Primary and essential
Includes:	N/A
Extends:	N/A
Cross-refs:	12,13,14
Use cases:	N/A

Number:	6.1
Use Case:	Lane Detection
Actors:	N/A
Description:	Make sure the car stays in the correct lane safely.
Type:	Primary
Includes:	1.1, 3.1
Extends:	N/A
Cross-refs:	10, 11, 13, 16, 17
Use cases:	N/A

Number:	6.2
Use Case:	Speed Control
Actors:	Brakes
Description:	Make sure the car is driving at a safe speed and safe distance.
Type:	Primary
Includes:	1.1
Extends:	N/A
Cross-refs:	9, 10, 12, 13, 14
Use cases:	N/A

4.2 Domain Model

This section provides a Domain Model of the HFDS, which describes how the system interacts with real world entities and the relationships between them. The first subsystem, Driver Assist uses the exterior cameras, and LiDAR, adaptive cruise control to check the status of the hardware and to see if conditions are safe to activate the system. The second subsystem, Driver Attention uses the interior cameras to check if the driver is paying attention. The third, Vehicle Position processes the position data used in Path prediction to calculate a path for the car. The Vehicle Control system calculates which way to turn the steering wheel, and whether to accelerate or decelerate. Lastly, the Human Machine Interface uses the audio system, seat, and dashboard to display warning signs to a driver who is not paying attention. All these subsystems are combined to make the Hands-Free Driving System. Figure 3 shows the domain model, describing the key components of the HFDS system and their relationship with one another.

Figure 3 is a UML Domain Model of the HFDS system. Domain models use class diagram notation. Each rectangle in the diagram represents an element of the system or an actor interacting with the system, also known as classes. Each class has a name, attributes, and methods. Class names are at the top and are bold. Attributes are below the names and represent data or state information for each class. Methods represent the functionality of each class and provide a way for classes to interact. Lines between classes represent connections or references between classes. The title of each line represents the kind of relationship the classes have (when applicable). The arrowed lines represent that one class knows or has access to an instance of another class. Lines with white diamonds represent aggregation; when one class has access to another class but does not depend on it. Lines with black diamonds represent composition; when instances of one class cannot exist without an instance of the other. There is no inheritance in Figure 3, so knowledge of generalization is irrelevant for this diagram.

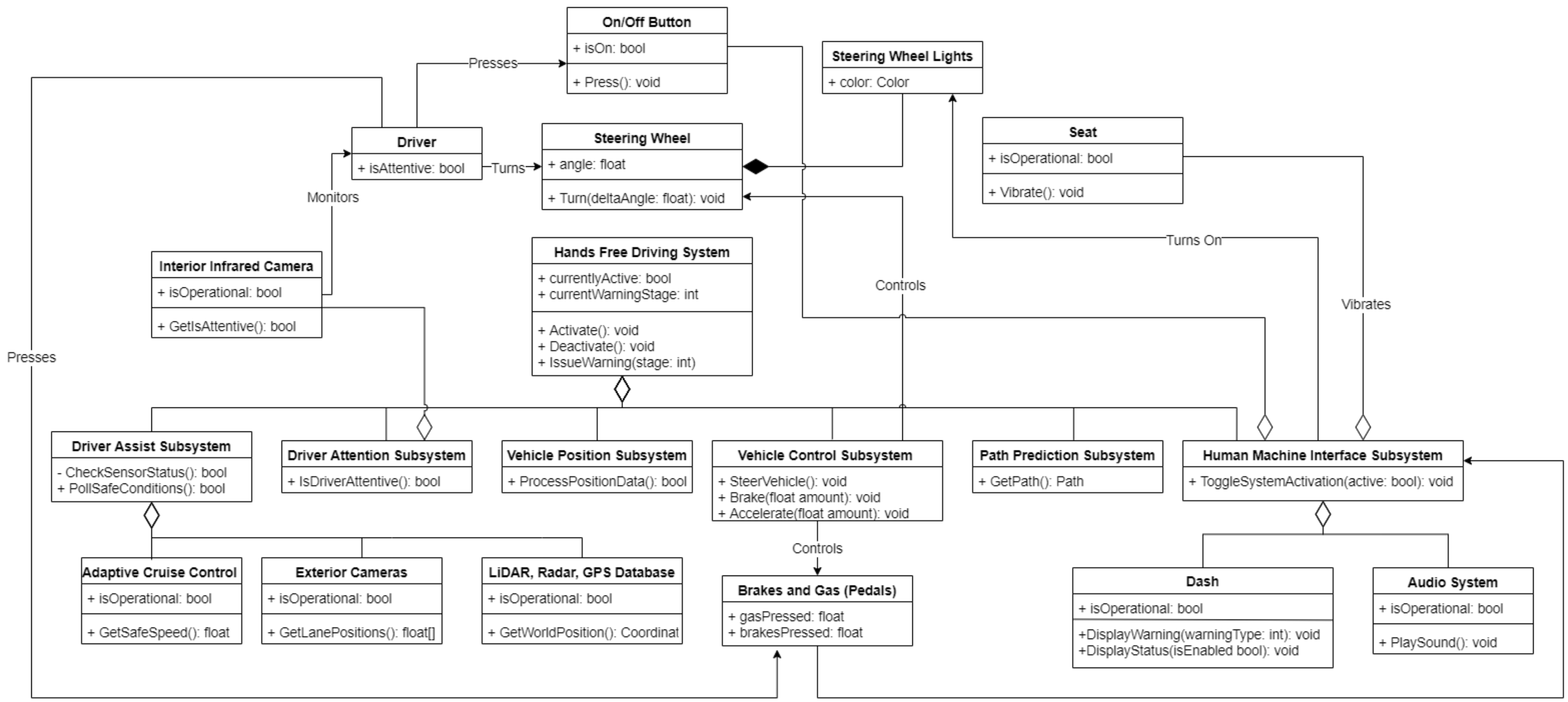

Figure 3: Domain model of the HFDS

The following is a data dictionary which details each class in the domain model and how each class relates to the other component of the system.

Element Name		**Description**
Adaptive Cruise Control		Helps determine the speed of the car.
Attributes		
	isOperational: bool	Checks to see if Adaptive Cruise Control is running.
Operations		
	GetSafeSpeed(): float	Obtains a speed that is safe for a projected trajectory.
Relationships	Adaptive Cruise Control is used by the Driver Assist Subsystem to adjust, or maintain speed.	
UML Extensions	N/A	

Element Name		**Description**
Audio System		Sound warnings for driver.
Attributes		
	isOperational: bool	Checks to see if the audio system is operational.
Operations		
	PlaySound(): void	Plays warning sound for the driver.
Relationships	Human Machine Interface Subsystem uses the audio system to warn the driver if they are not paying attention.	
UML Extensions	N/A	

Element Name		**Description**
Brakes and Gas (pedals)		Controls the speed of the car.
Attributes		
	brakesPressed: float	Slows down the car. 0-1 is the amount of pressure the driver or the HFDS applies to the brake pedal.
	gasPressed: float	Accelerates the car. 0-1 is the amount of pressure the driver or the HFDS applies to the gas pedal.
Operations		
	N/A	
Relationships	The Vehicle Control Subsystem controls the pedals. Also, the driver can control the pedals manually.	
UML Extensions	N/A	

Element Name		**Description**
Dash		Displays warning for the driver.
Attributes		
	isOperational: bool	Checks to see if the dash is operational.
Operations		
	DisplayWarning(warningType: int): void	Displays warning signs on the dashboard.
	DisplayStatus(isEnabled: bool): void	Displays the status of the HFDS, either it is enabled or disabled.
Relationships	Human Machine Interface Subsystem uses the Dash to display warning signs for the driver.	
UML Extensions	N/A	

Element Name		Description
Driver		The user driving the vehicle.
Attributes		
	isAttentive: bool	Tells whether the driver is paying attention or not.
Operations		
	N/A	
Relationships	Presses the On/Off Button, presses brakes and gas pedals, turns the steering wheel, and is monitored by the Interior Infrared Camera.	
UML Extensions	N/A	

Element Name		Description
Driver Assist Subsystem		Checks for safe conditions and issues commands.
Attributes		
	N/A	
Operations		
	CheckSensorStatus(): bool	Checks whether all sensors are operational.
	PollSafeConditions(): bool	Retrieves information from sensors and determines whether the vehicle is safe to activate HFDS.
Relationships	Gets data from exterior cameras, LiDAR, Radar, GPS, and Adaptive Cruise Control.	
UML Extensions	N/A	

Element Name		**Description**
Driver Attention Subsystem		Ensure the driver is paying attention to the road and initiates warnings if not.
Attributes		
	N/A	
Operations		
	IsDriverAttentive(): bool	Checks if the driver is attentive.
Relationships	Uses data from the interior infrared camera to determine driver attentiveness.	
UML Extensions	N/A	

Element Name		**Description**
Exterior Cameras		Cameras to help create a path for the Driver Assist System.
Attributes		
	isOperational: bool	Checks to see if outside cameras are operational.
Operations		
	GetLanePositions(): float[]	Gets current lane positions at a given moment.
Relationships	Aggregated with the Driver Assist Subsystem.	
UML Extensions	N/A	

Element Name		**Description**
Hands-Free Driving System		The central class which manages all subsystems which implement Hands-Free Driving.
Attributes		
	currentlyActive: bool	Tells whether the HFDS has been activated or not.
	currentWarningStage: int	The stage of the warning currently being displayed by the HFDS.
Operations		
	Activate(): void	Turns HFDS on.
	Deactivate(): void	Turns HFDS off.
Relationships	Aggregated with the Driver Assist Subsystem, the Driver Attention Subsystem, the Vehicle Control Subsystem, the Path Prediction Subsystem, and the Human Machine Interface Subsystem.	
UML Extensions	N/A	

Element Name		**Description**
Human Machine Interface Subsystem		Accepts input from the driver and issues warnings.
Attributes		
	N/A	
Operations		
	ToggleSystemActivation(): void	Change the activation status of the HFDS.
	SendControlWarning(stage: int): void	Sends warning commands to Steering Wheel, Seat, Dash and Audio System.
Relationships	HFDS activated when the driver presses the button based on safe conditions. Sends out warning commands to Steering Wheel, Seat, Dash, and Audio System.	
UML Extensions	N/A	

Element Name		**Description**
Interior Infrared Camera		Detect if the driver is paying attention.
Attributes		
	isOperational: bool	Checks to see if the camera is operational.
Operations		
	GetIsAttentive(): bool	Checks to see if the driver is paying attention.
Relationships	Driver Attention Subsystem uses the Interior Infrared Camera to detect if the driver is paying attention.	
UML Extensions	N/A	

Element Name		**Description**
LiDAR, Radar, GPS Database		Help determine the path for Hands-Free Driving.
Attributes		
	isOperational: bool	Check to see if the LiDAR, Radar, GPS Database are operational.
Operations		
	GetWorldPosition(): Coordinates	Grabs world coordinates of the car.
Relationships	The Driver Assist Subsystem uses LiDAR, Radar, and GPS database to predict the correct path.	
UML Extensions	N/A	

Element Name		**Description**
On/Off Button		Interacted by the driver to turn on or off HFDS.
Attributes		
	isOn: bool	Determines whether the HFDS is activated.
Operations		
	Press(): void	Pressing the button to activate or deactivate HFDS.
Relationships	Pressed by Driver, aggregated with Human Interface Subsystem.	
UML Extensions	N/A	

Element Name		**Description**
Path Prediction Subsystem		Calculates projected path for a vehicle based on information from sensors and other systems.
Attributes		
	N/A	
Operations		
	GetPath(): Path	Determines safe projected trajectory of the car.
Relationships	N/A	
UML Extensions	N/A	

Element Name		**Description**
Seat		The seat of the vehicle that will vibrate to get the driver's attention.
Attributes		
	isOperational: bool	Checks to see if the dashboard hub is operational.
Operations		
	Vibrate(): void	Send warning vibrations to the driver's seat.
Relationships	Human Machine Interface Subsystem uses the Dash to display warning signs for the driver.	
UML Extensions	N/A	

Element Name		**Description**
Steering Wheel		Rotated by the driver or controlled by the Vehicle to steer the vehicle.
Attributes		
	angle: float	The angle at which the steering wheel is positioned.
Operations		
	Turn(float changeAngle): void	Turn the steering wheel based on the angle it is positioned in.
Relationships	Turned by Driver, controlled by Vehicle Control Subsystem, owns Steering Wheel Lights (Composition).	
UML Extensions	N/A	

Element Name		**Description**
Steering Wheel Light		The light is managed by HFDS to notify the driver of the status of HFDS.
Attributes		
	color: Color	The color of the light on the steering wheel.
Operations		
	N/A	
Relationships	Owned by Steering Wheel (composition), used by the Human Machine Interface Subsystem.	
UML Extensions	N/A	

Element Name		Description
Vehicle Control Subsystem		Accepts input and sends commands to steer/accelerate/brake.
Attributes		
	N/A	
Operations		
	Brake(float amount): void	Changes the amount of input for the braking system.
	Accelerate(float amount): void	Changes the amount of input for the accelerator.
	SteerVehicle(): void	Changes the steering angle of the steering wheel.
Relationships	Control the brakes and gas pedals, turn the wheel.	
UML Extensions	N/A	

Element Name		Description
Vehicle Position Subsystem		Process sensor data from the real world to determine the relative position of the vehicle.
Attributes		
	N/A	
Operations		
	ProcessPositionData(): bool	Process data from the Driver Assist System and determines the position of the vehicle.
Relationships	Aggregated with the Hands-Free Driving System.	
UML Extensions	N/A	

4.3 Sequence Diagrams

Figures 4, 5, 6, 7, 8, and 9 are the sequence diagrams that portray how the Hands-Free Driving System operates for different use cases. In each sequence diagram, it highlights the sequence of the interactions between the active objects in the HFDS. The boxes from left to right are the elements that are involved in the use case while the vertical rectangles represent the period at which the element is performing the operation. The solid arrows represent the communication between the elements in the use case while the dashed arrows indicate a return message that gives information back to the boxed object calling the message.

Figure 4 describes the starting process of Hands-Free Driving mode where it checks for safe conditions and notifies the driver of the Hands-Free Driving status.

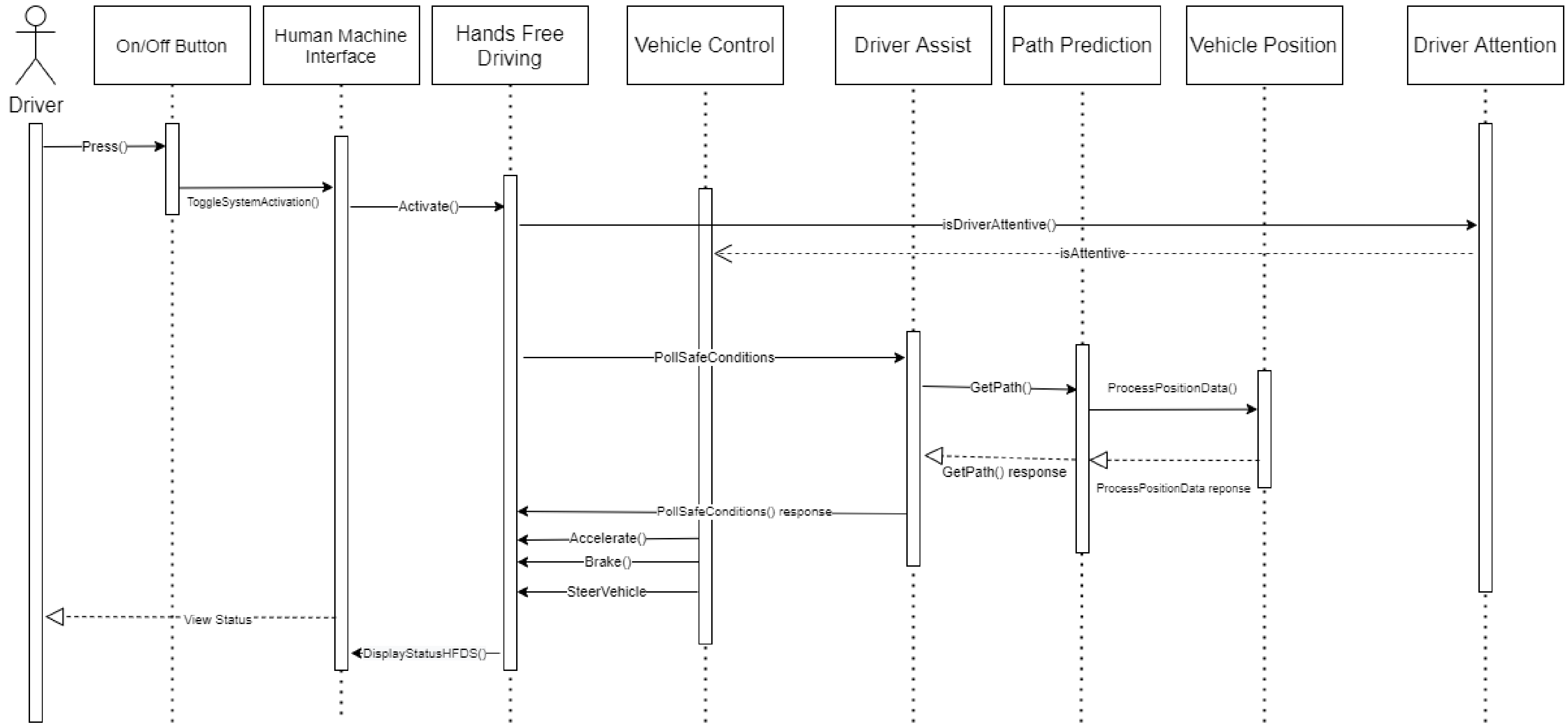

Figure 4: Starting Process for Hands-Free driving system to evaluate and display status to driver

Figure 5 illustrates the main functionalities of the hands-free driving when the hands-free driving mode is enabled. The system continuously checks if the driver is in safe conditions to which the vehicle is controlled in a safe manner.

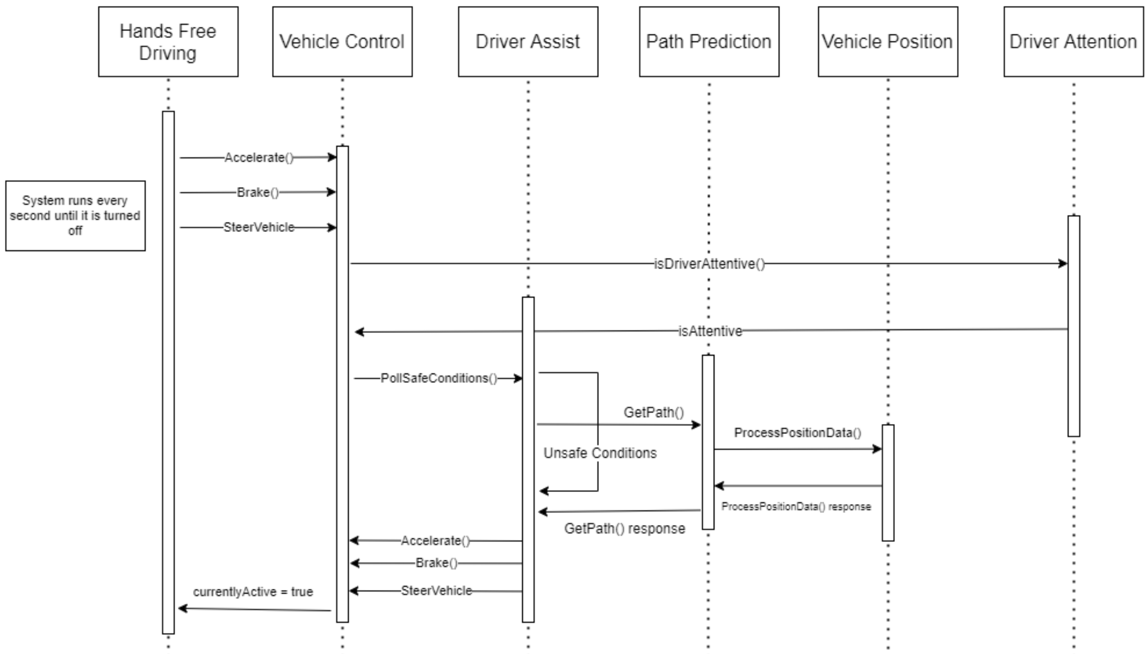

Figure 5: Main Functions for HFDS

Figure 6 describes the system response to when the driver is being inattentive. It will alert the user in two ways, either on the dash or audio cues. If the driver remains inattentive, the vehicle will safely navigate to a stop.

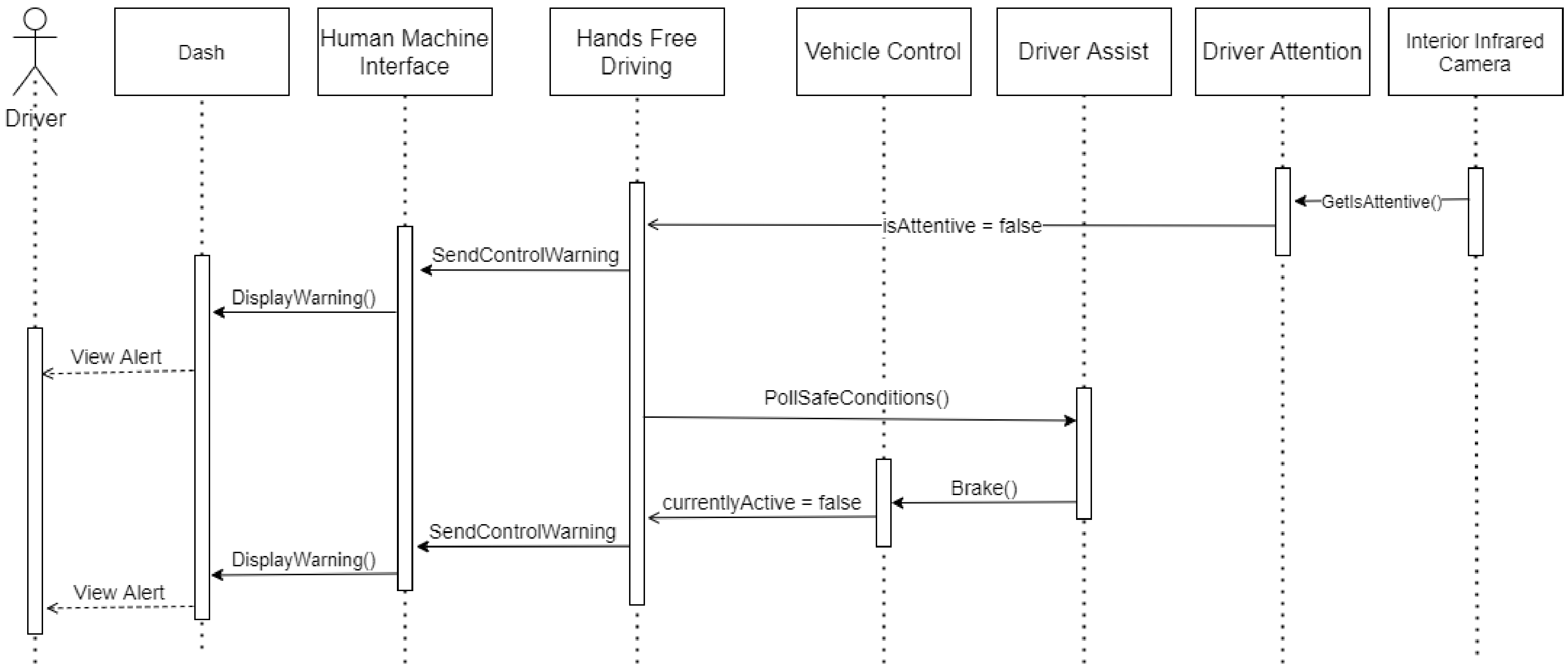

Figure 6: Sequence Diagram when the driver is attentive

Figures 7, 8, and 9 showcase the driver regaining control from the hands-free driving system. The driver has multiple ways of turning off the system with the means of using the on/off button, steering the wheel, and pressing on the pedals.

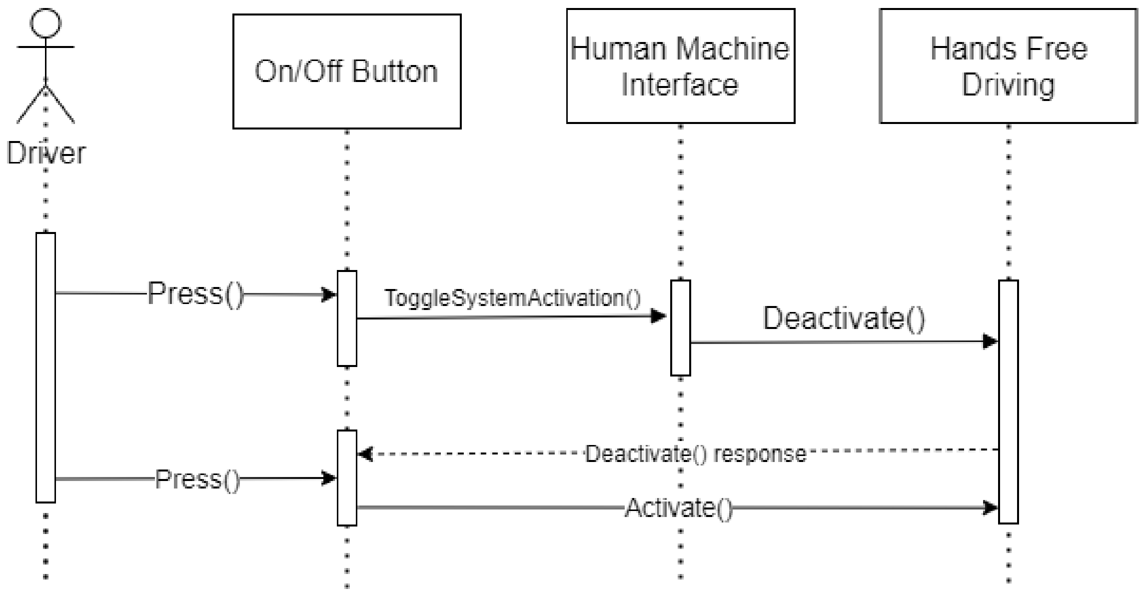

Figure 7: Sequence Diagram for driver regaining control temporarily from HFDS via On/Off Button.

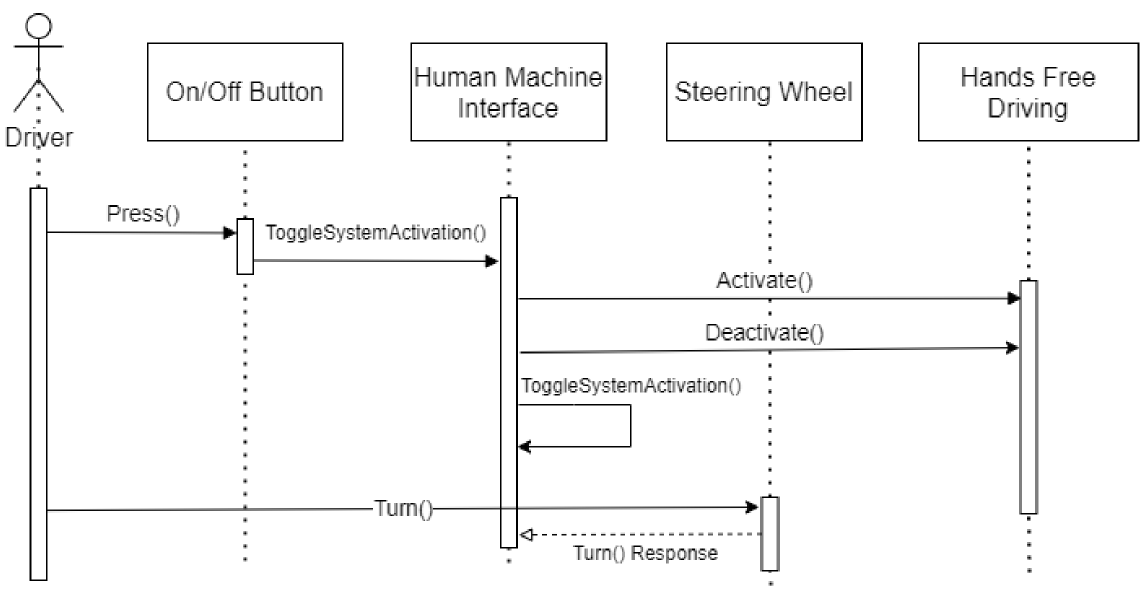

Figure 8: Sequence Diagram for driver regaining control from HFDS via turning Steering Wheel

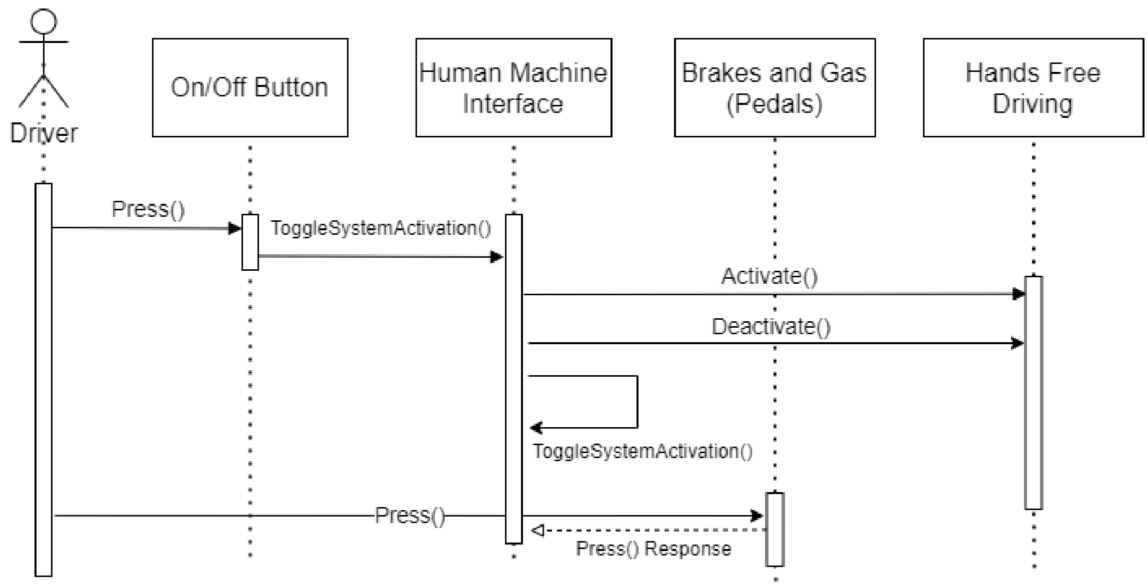

Figure 9: Sequence Diagram for driver regaining control from HFDS via pressing the gas and brake pedals

4.4 State Diagrams

Below are several state diagrams for classes in our system. A state diagram is a collection of states that a class can be in and transitions between those states. A state is represented by the rounded rectangles with the name of the state. The initial state is denoted by a filled black circle while the final state is denoted by a circle with a dot in the middle. The arrows are the transitions from one state to another. For each transition, there could be a trigger, a guard and an effect. A "trigger" is the cause of the transition. A "guard" is a condition which must be true in order for the trigger to cause the transition. An "effect" is an action which can trigger the source state based on the guard condition. The system can remain in a state for a finite period of time and is satisfied by certain conditions from performing certain actions.

Figure 10 is a state diagram for the Hands Free Driving System class which manages all the other subsystems, activation of HFDS, and warning stages. Figure 11 is a state diagram representing the Driver Assist Subsystem, which manages and verifies sensors and external conditions. Figure 12 is a state diagram representing the Driver Attention Subsystem, which tracks eye and head movement to verify that the driver is actively engaged with the road. Together they represent the states that the system can be in as a whole, since the other subsystems don't have varying states and are instead used for computations, vehicle control, and managing interfaces.

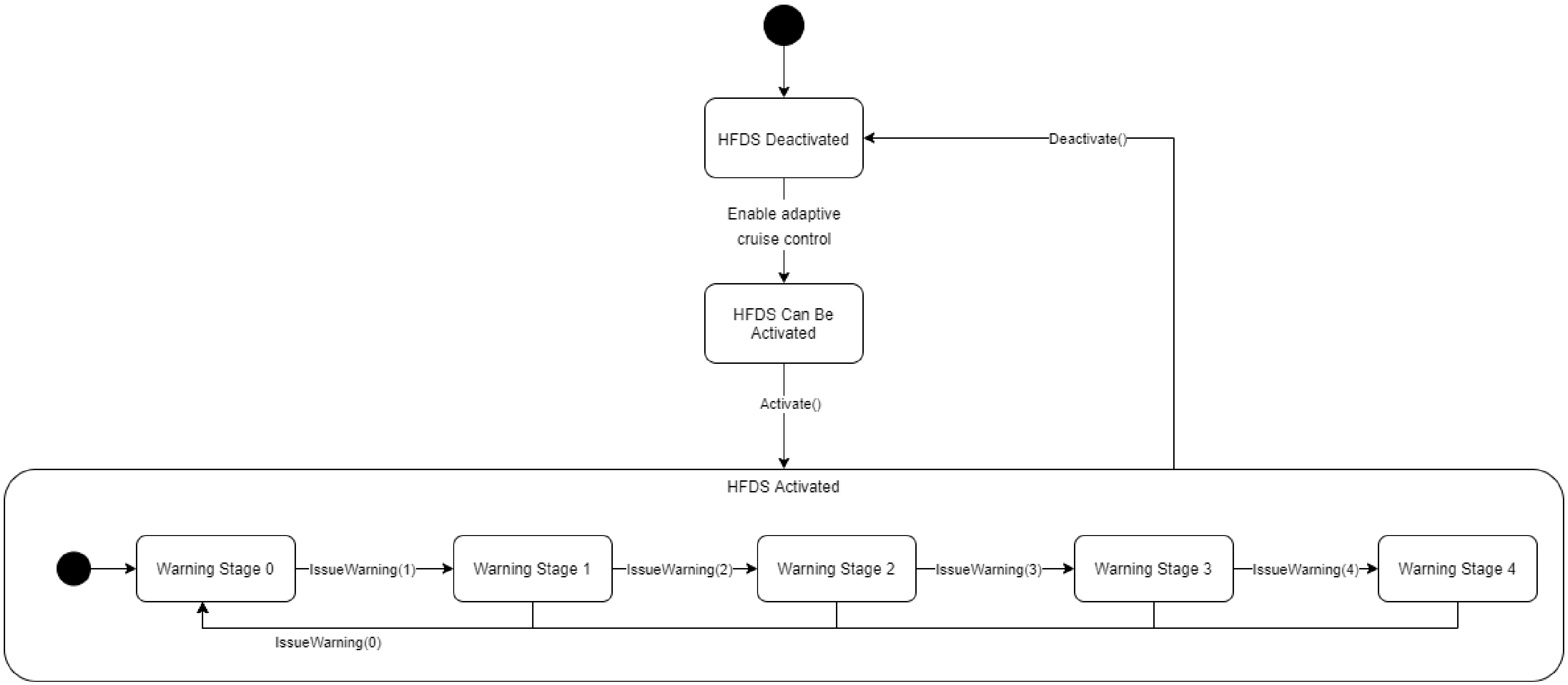

Figure 10: State Diagram for the Hands Free Driving System class.

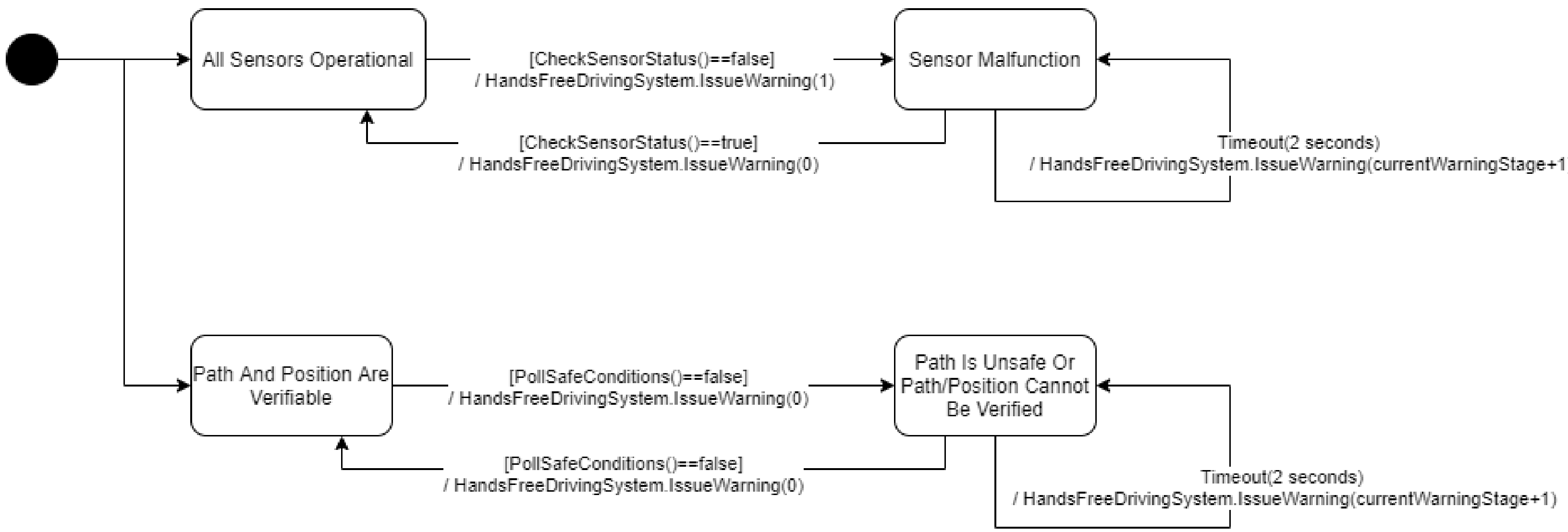

Figure 11: State Diagram for the Driver Assist Subsystem class.

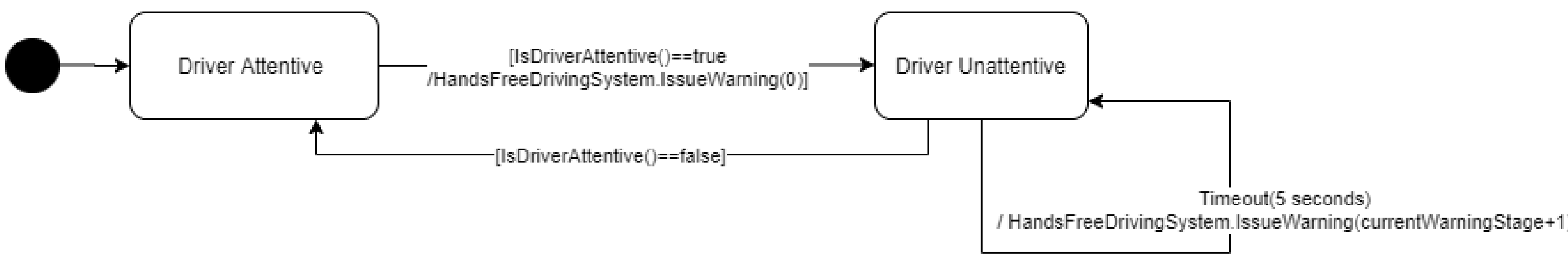

Figure 12: State Diagram for the Driver Attention Subsystem class.

5 Prototype

A prototype is provided to showcase the conditions in which the HFDS can turn on, how it turns off, and its behavior when it encounters an obstacle. It is a simplistic representation in which most conditions are not as nuanced as the final version will be, and the functionality of the interior cameras, adaptive cruise control and lane detection are more simplistic than the final versions will need to be. The prototype should, however, serve to give an idea of how a more complete system would function. For this prototype we modeled our system on the scenarios requested in the original requirements document provided to us, and functionality is mostly based on that document. The prototype was developed using Unity, and the final prototype was built to WebGL to work in browsers.

In terms of system functionality, the prototype consists of a box (representing a car) with a seat and driver (sphere) on top. The car can be driven when HFDS is not active. When the Hands-Free Driving System is turned on using the button at the top left, the vehicle will drive along a predetermined octagonal path (simulating lane detection). The system will only activate if all sensors are operational, the adaptive cruise control is operational, and a collision is not imminent. If any of those conditions are no longer met while the HFDS is active, it will show several stages of warnings, slowing to a stop in the fourth stage. Obstacles can be placed at the corners of the octagonal path to simulate obstacles on the highway. The system will not always slow to a stop in time to avoid a collision with these obstacles because of their placement at fixed points in the path. The driver will be prompted to retake control faster if a collision is imminent or if a sensor fails than if the system determines that the driver is not paying attention. When a warning stage to retake control is reached, text will appear at the top left explaining steps that will be taken, the vehicle's color may change, and the seat will vibrate at the third stage. The driver can also supply manual input to the car while HFDS is active, which temporarily pauses HFDS, and if input is continuously supplied, HFDS will disengage completely.

5.1 How to Run Prototype

Any up-to-date browser should be capable of running the prototype, though many browsers do not allow running the prototype directly from a computer's file system under normal circumstances. If running the prototype locally becomes problematic, the prototype can be run at the following link:

https://developer.cloud.unity3d.com/share/share.html?shareId=WywgZc1L_8

The prototype should work on any operating system with an up-to-date web browser and should not require any additional plugins. If that does not work, additional instructions are included in the README.txt file included with the build's .zip folder for running locally.

5.2 Sample Scenarios

The prototype should demonstrate functionality in a variety of scenarios. For simplicity we will explain the scenario in which the driver activates the system, which functions correctly, and then stops paying attention to the road:

Scenario: All sensors are operational, GPS and LiDAR are functional and agree on the vehicle's position, and the vehicle is on a "highway" which is valid for HFDS to start (Figure 13). The driver activates HFDS (via a button in version 1 of the prototype), and the car begins steering itself along a path (predetermined in the prototype). The vehicle drives itself for a while with no input from the driver, and at some point, the driver stops paying attention (Figure 14). The internal camera detects this after a few seconds and the system issues a level 1 warning (Figure 15). Another 5 seconds pass and the driver is still not paying attention, so the system issues a level 2 warning (Figure 16). If another 5 seconds pass and the driver is still not paying attention, a level 3 warning is issued (including seat vibrations) (Figure 17). After a final 5 seconds pass, the vehicle issues a level 4 warning and begins slowing down the vehicle and turns on the hazard lights (Figure 18). When the vehicle comes to a stop HFDS deactivates, leaving hazard lights on (Figure 19).

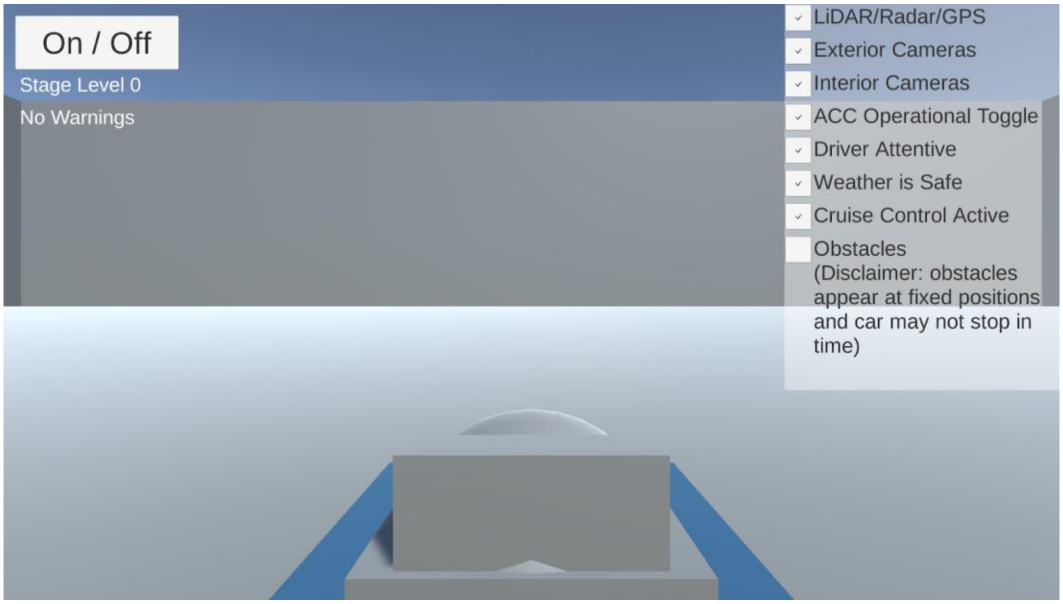

Figure 13: HFDS system operational but inactive

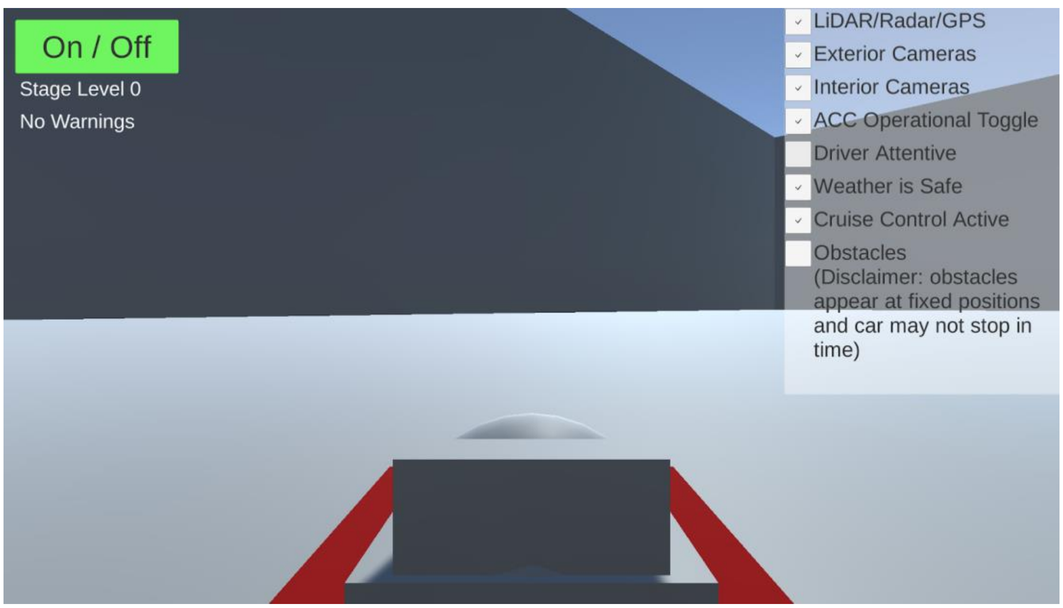

Figure 14: HFDS system is active. Driver is inattentive.

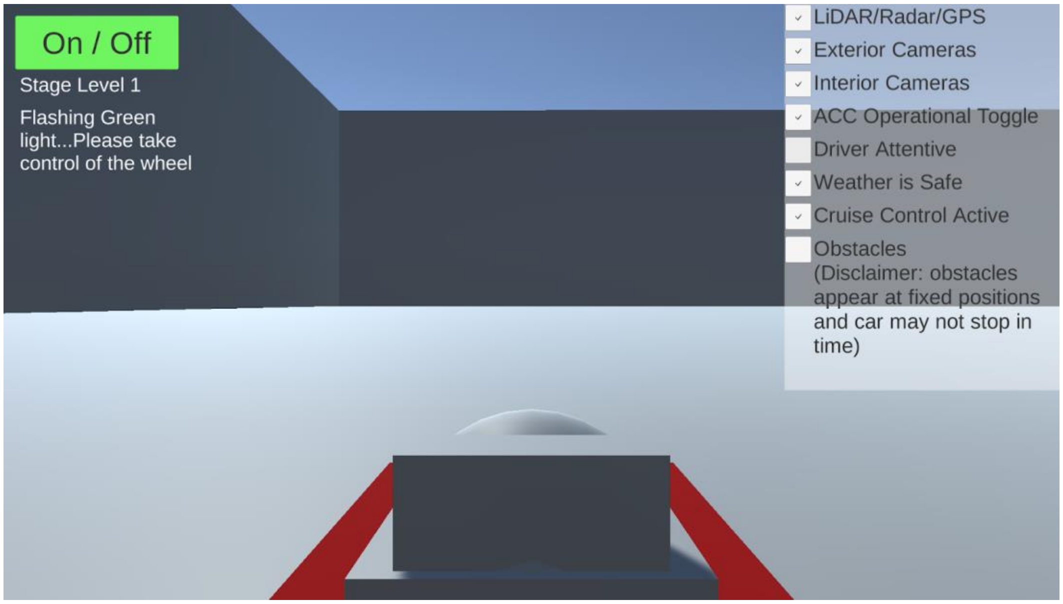

Figure 15: Stage 1 warning. Steering wheel lights flash green.

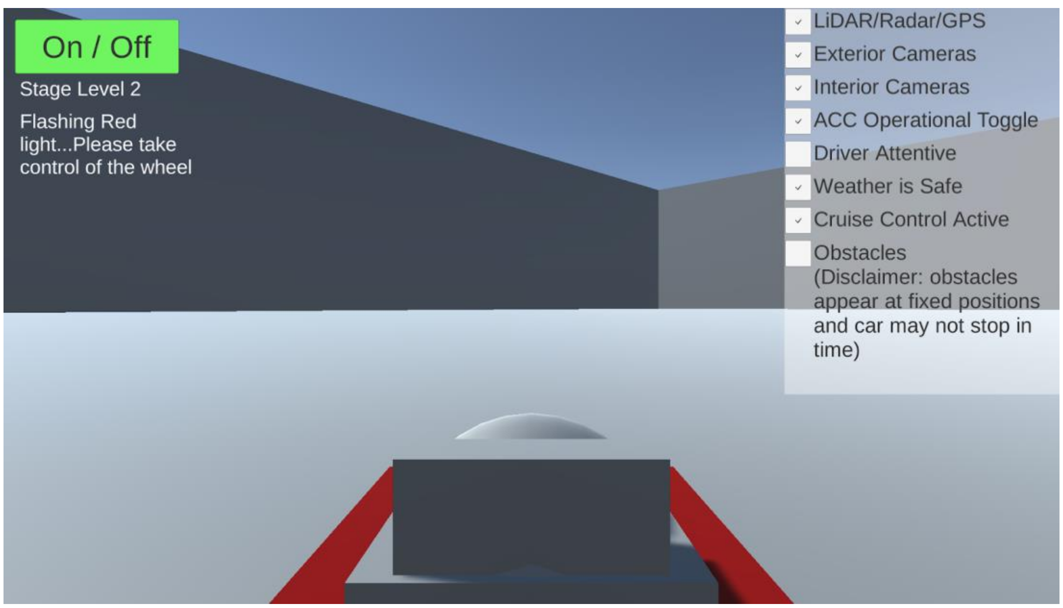

Figure 16: Stage 2 warning. Steering wheel lights flash red, text prompt to retake control.

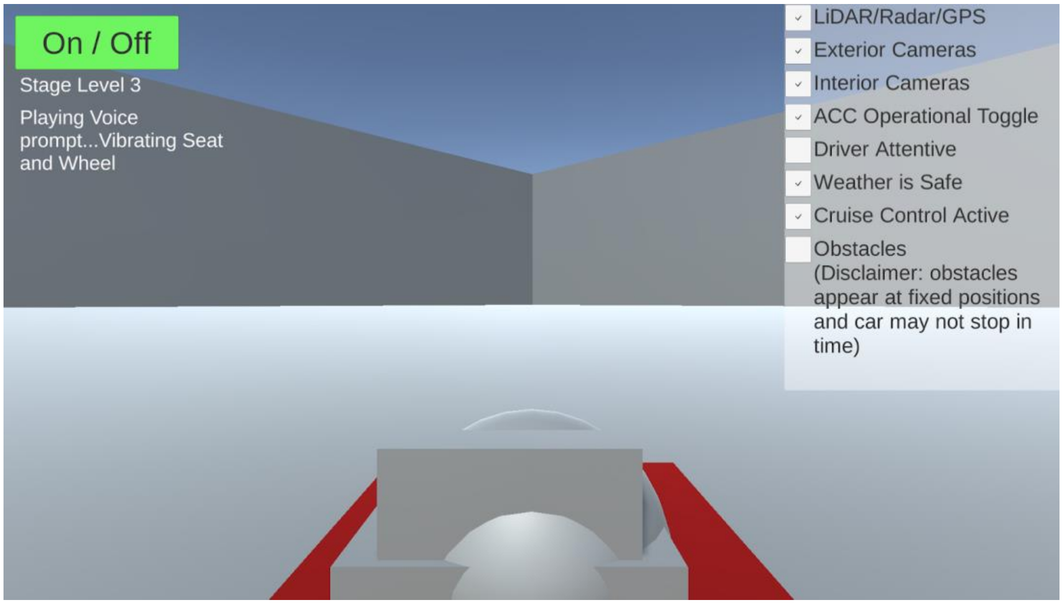

Figure 17: Stage 3 warning. Voice prompt and seat vibrations.

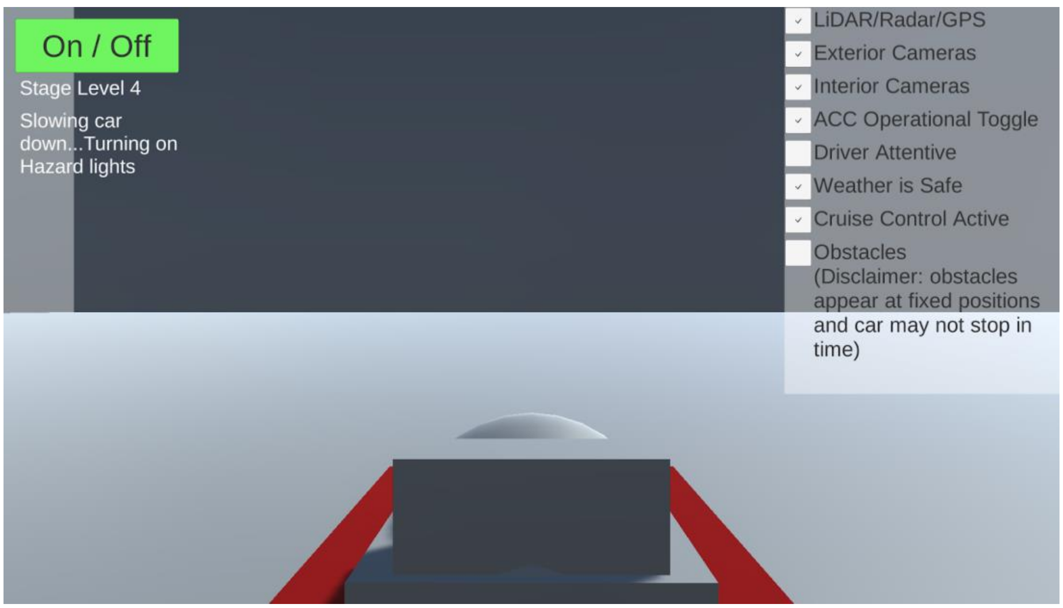

Figure 18: Stage 4 warning. Hazard lights turn on, car slows down.

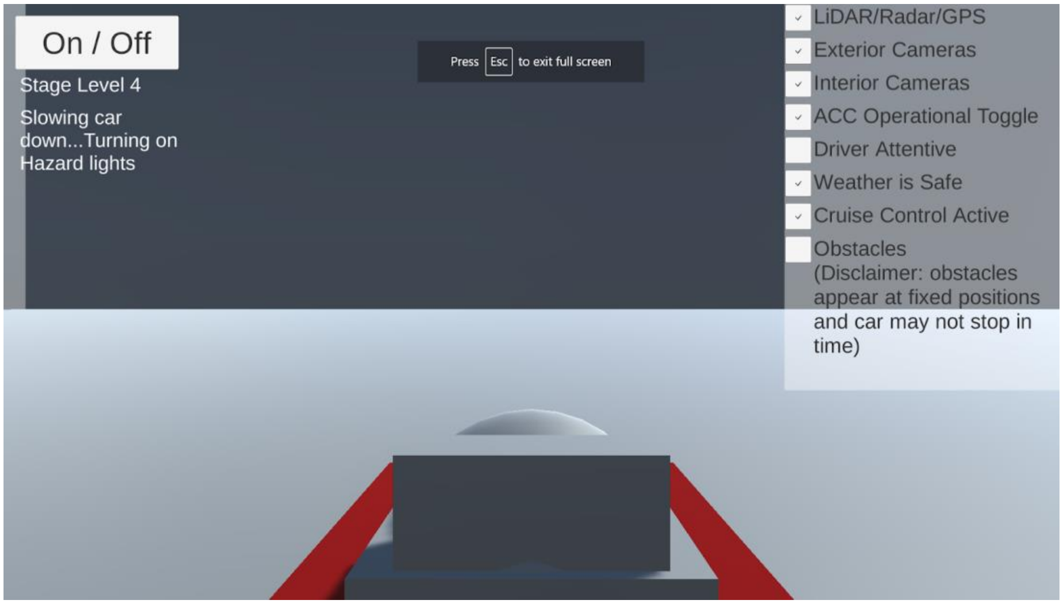

Figure 19: Vehicle comes to a stop. HFDS deactivates. Hazards remain on.

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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.