Software Requirements Specification (SRS)

Project Lane Management System (LMS)

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1 Introduction

When looking at vehicle accident statistics, tens of thousands are injured or killed each year by incidents where a vehicle has left their lane unintentionally [3]. Furthermore, the most deadly type of roadway departure collisions are head-on collisions. Head-on collisions were the cause of 14% of all U.S. traffic fatalities in between 2016 and 2018 [2]. We can develop technologies to combat these terrible tragedies by way of a system that prevents lane drifting and unwanted lane departure.

This document details the requirements and expected elements and functionality of the Lane Management System (LMS). The LMS is an assistance system to prevent the driver's vehicle from lane drifting. Section 1 we can find the purpose and scope of the system as well as a guideline to definitions, acronyms, and abbreviations used throughout the document and a description of the overall organization of the document.

1.1 Purpose

The purpose of this Software Requirements Specification document is to provide information to interested parties, developers, stakeholders, management, etc. The SRS document is intended to provide a detailed understanding of the software requirements needed for the development of the LMS system that will behave and operate as expected.

1.2 Scope

The LMS is an embedded automotive system. The LMS is designed to increase convenience and safety when driving. It will serve as an assistance to the driver and will not be used as a substitute for careful driving and will only provide brief redirection. It is not meant to be a hands free driving system.

The LMS is composed of smaller subsystems including the Lane Keeping System (LKS) which contains a camera system and evaluates the vehicles position in the lane as well as redirecting the vehicle if needed, Display System (DS) which alerts the driver if they are possibly drifting out of their lane and a deactivation system which will deactivate the system via driver override or if lane markings are not detected. The LMS has cameras and sensors to monitor the vehicle and its position in the lane. When the LKS detects possible lane drifting the DS will display a warning message and re correct the vehicles positioning if needed. The driver is able to override the lane correction by taking control of the steering wheel or turning on their turn signal. If there is ambiguity or no lane markings detected the display system will alert the driver that the LMS is not currently in effect and is not detecting the vehicles position at that time. The display will inform the driver to remain alert while driving. The LMS's goal is to assist the driver in remaining centered in their lane and will provide constant feedback with the driver about the status of the system and alerts them before taking any action.

1.3 Definitions, acronyms, and abbreviations

- LMS: Lane Management System, the overall system\
- LKS: Lane Keeping System, the subsystem that handles the lane centering of the vehicle.
- DS: Display System
- LCS: Lane Centering System
- SRS: Software Requirements Specification document
- GUI: Graphical user interface

1.4 Organization

Following Section 1, the document is organized as follows:

Section 2: You can find an overall description for the LMS system as well as a detailing of the system's functions, characteristics, constraints, assumptions, dependencies and possible future improvements.

Section 3: Includes an enumerated list of requirements for the LMS.

Section 4: Contains visual representations and models of expected behaviors and functionality of the LMS system. In this section we can find various use case diagrams, high level class diagrams, and state diagrams for all key classes.

Section 5: Describes how the prototype can be utilized to display the LMS's functionality.

Section 6: Lists all of the sources referenced throughout the SRS document.

Section 7: Listed here is a point of contact if more information is needed.

2 Overall Description

The following sections shall describe in depth how the LMS operates in a vehicle. Section 2.1 outlines the perspective of the system along with the constraints on the system. Section 2.2 outlines the functions that the software shall perform. Section 2.3 describes the expectations the users shall have when using and operating the system. Section 2.4 describes the additional constraints placed on the system. Section 2.5 describes the assumptions and dependencies on the LMS. Finally, in Section 2.6 approportioned requirements shall be described.

2.1 Product Perspective

The LMS is a product in vehicles that is responsible for keeping the vehicle centered in the driving lane and to prevent any unintentional lane switching. The system is an independent feature in the car, however it comprises several other subsystems which all rely upon each other in order for the LMS to function to its highest extent. The subsystems include a DS, LKS, and a system that acts to disable the main LMS. Even though the LMS is an independent system in the vehicle, the communication between all of its subsystems is vital for optimized performance in the system.

User role is vital in the overall system, and contributes to many of the system's functions. The user must be able to operate the vehicle which includes functions such as steering, acceleration, deceleration, and turn signal usage. Along with these functions, the user must be able to see and understand the car's dashboard GUI in order for the user to understand the warnings and signals the LMS is showing. Lastly, the user must be able to disable the system by turning off the system via a button or if the vehicle's speed is not above 35 miles per hour.

Hardware components are also a vital part to the success of the system. Cameras are placed on the sides of the vehicle so the lanes are able to be detected. The dashboard of the vehicles must include a visual display in order for warnings and signals to be detected by the user. Sensors are also found along the sides of the vehicles which determine the speed, steering angle and road curvature for the system. No other main hardware component is needed for optimal functionality of the system.

The system needs to have software components that allow for accurate information passing between the subsystems of the LMS. Fast and accurate information communication is needed in the subsystems so that the correct response is chosen by the main system. The substems provide and calculate data such as distance to lane and determining the angle the car is driving. Without good communication between the subsystems, there is a possibility of accidents and an overall unreliable LMS.

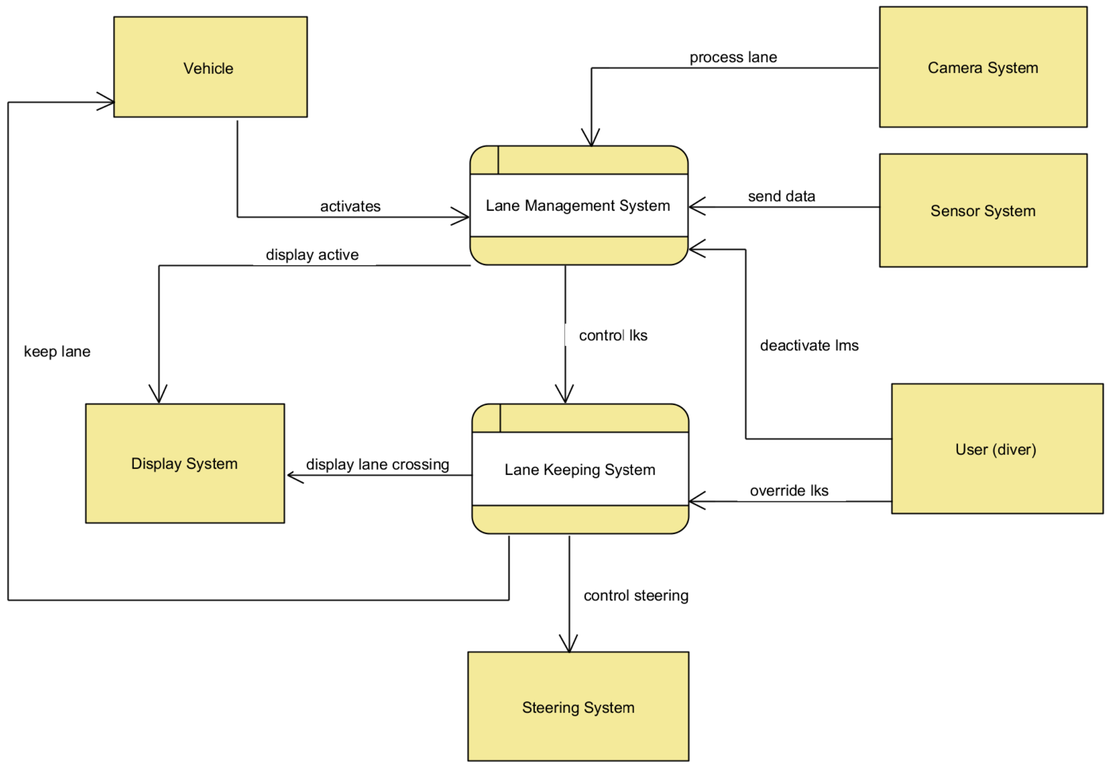

Figure 1: The data flow diagram above shows how information and actions flow in the system. The vehicle is the main actor in the diagram and is what activates the systems. Cameras and Sensors are both vital for sending information to the system in order to understand the distance to the lane markers. The Lane Management System is responsible for receiving information from the sensors and calculating if the car is about to cross the lane. The Lane Keeping system is activated when there is about to be a breach in the lane, and results in overriding the steering to move the car back to the center of the lane. Displays for lane crossing, unintentional swerving, and if the system is active are all found in the DS.

2.2 Product Functions

The LMS is an assistance tool for the vehicle to be able to be centered in its given lane or to prevent any unintentional lane switching. The high-level goal is to provide safety for the driver by keeping the vehicle in the lane they should be in. Safety is provided by using many different systems in the vehicle, such as cameras and sensors which accurately provide data as to where the lane markers are. The vehicle shall keep inside its current lane regardless of speed, road curvature, and low visibility of lane markers. Warnings shall be displayed in the dashboard display which indicate if the LMS is active and if a lane is about to be breached.

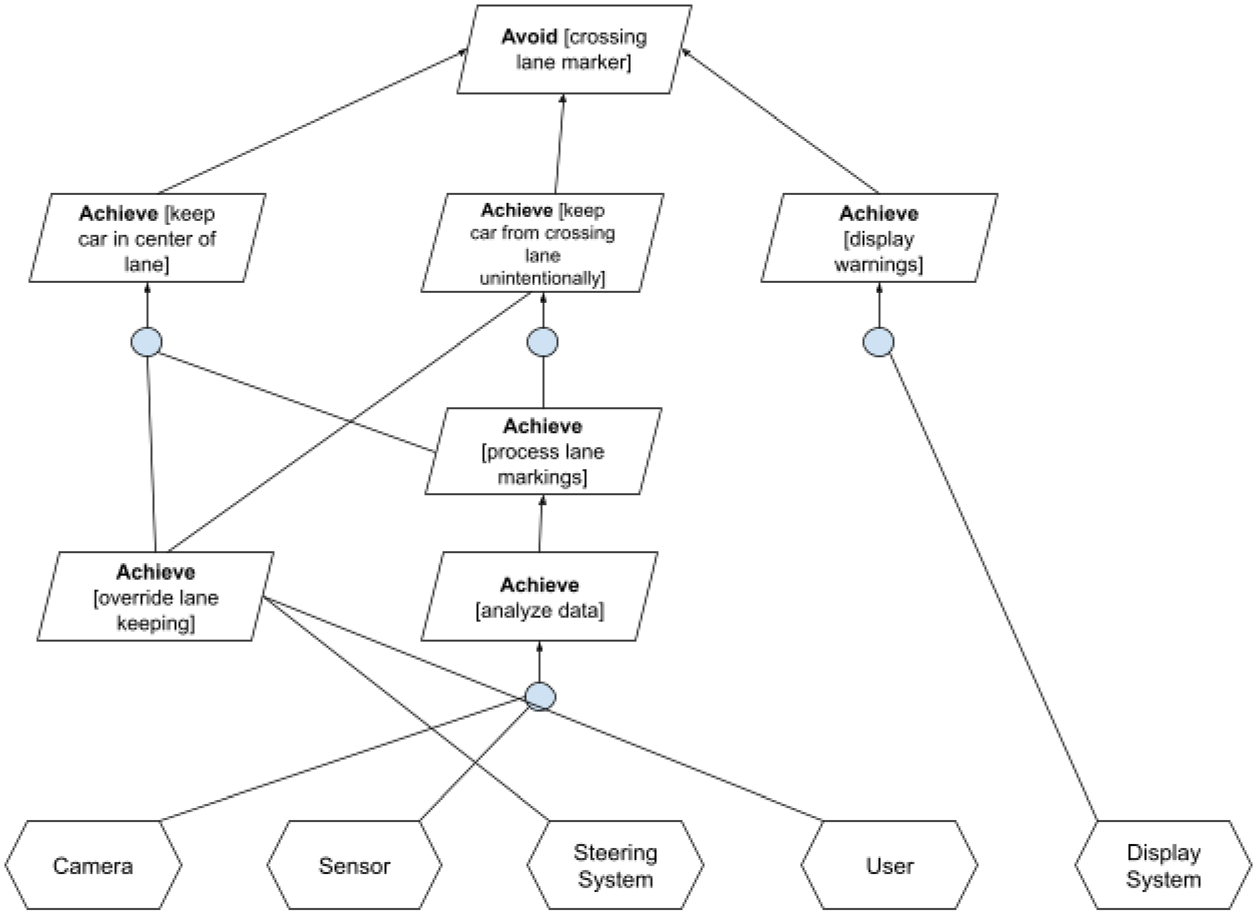

Figure 2: The figure above shows a high-level goal diagram for the LMS. At the top, the main goal of the system is presented which is to avoid crossing the lane markers. Branching off of the main goal, the system is to keep the car in the center of the lane, avoid crossing the lane unintentionally, and to warn the user if the lane is about to be breached. In order to achieve these goals, the lane markers and data needs to be processed and sent to the system. Cameras and sensors help to gather the data needed. The user is able to override the system by using turn signals or applying enough torque to the steering wheel to indicate a lane switch.

2.3 User Characteristics

The expectations for a user of the LMS are described here. In order for the user to operate and use the system, they must have passed the drivers test and have a valid driver's license. The user must be able to follow all of the rules and regulations of the road in the given location of operation. Along with following the rules, the user must be able to have full functionality of the acceleration, braking, steering wheel, and turn signals. The user should be able to see the displays given on the dashboard and also be able to hear any sound warnings the system presents. Finally, the user should use the system as a driving assistance instead of any form of autonomous driving feature.

2.4 Constraints

The constraints set for the LMS are presented in this section. The system is only able to become active when the vehicle is set to drive mode and the current speed of the vehicle is at or above 35 miles per hour. While the system is active, the camera and path detection system must be able to operate if the lanes are fully present, if there is any curvature on the road, and if there is limited visibility of the given lanes. When the lane detection is not able to operate the system must either deactivate and let the driver know, or use GPS lane detections in order to calculate the path of the car. The correct detection of the lanes is a safety-critical property due to the potential risk if the system fails. With failure, there are possibilities of accidents and other life-threatening circumstances.

Another safety-critical property is for the cameras and sensors to be fully operational and weather conditions to be optimal. If the cameras are damaged or obstructed there may be discrepancies when detecting the correct lane distance. If weather conditions are not optimal, such as snow or heavy rain, the cameras and sensors may not be able to detect the lane markers. If any of the sensors or cameras are not operational, the system should not be able to be activated, and a warning should be displayed on the dashboard telling the user the system is not active.

Other constraints include the ability to disable the system correctly. The system must be disabled if the user activates the turn signal to indicate they are switching lanes, and if the user applies enough torque on the steering wheel which overrides the system. Without the ability to disable the LMS, there is a huge risk of accidents or unintentional lane keeping , thus making this a very important safety-critical property.

Finally the LMS must be able to display and provide sound warnings. The user must be warned if there is any form of unintentional swerving, the lane is about to be breached, and if the system is disabled. Warnings are vital to the system in order to provide the user with the most updated information about what is going on with the system and if there is any potential danger while staying in the lane. The communication between the user and the system is vital in order for the most safe and optimal driving experience possible.

2.5 Assumptions and Dependencies

In order for the LMS to be fully operational, all of the specified hardware components must be installed properly in the vehicle. The cameras and sensors must be fully operational for the system to be successful. Software in the system must include communication between all of the LMS’s subsystems and also be able to gather basic information from the vehicle such as speed and direction. In optimal weather conditions and environments the system must be able to operate fully without fail. When lane markings are present or if there is any curvature in the road, the system must operate fully and be able to fulfill its operations of lane management. The user must be fully aware of all of the warnings and actions the LMS is able to perform, and understand that the system is only for driving assistance.

2.6 Approportioning of Requirements

The scope of the LMS is limited in size but in the future, the requirements could be improved to include more functionality. One additional requirement would be for the cameras to be able to detect if there is another vehicle in the lane that is about to be switched to. The ability to detect other vehicles can improve the overall safety of the user. Another requirement would be to have a display for possible cameras or sensors that are either not functioning or an outside factor is not allowing them to work properly. The final requirement would be the ability to change any setting such as warning tone or the type of visual display that shows up on the dashboard.

3 Specific Requirements

3.1 Primary Requirements:

1. The system will have a lane management system.

    a. If the system detects that you are not near a certain range of the center of the lane, it will enable the system to override and take over to gently move you back into the center at a safe speed.

    b. Users will be able to override the lane keeping assistance through pulling the wheel.

2. The system will have a lane departure warning system.

    a. The User Interface System shall accurately update the driver about the vehicle's positioning in the lane, using the calculations of the Path prediction Subsystem.

    b. The system will alert the driver in some way if it has found the vehicle is drifting.

    c. There shall be a warning signal in the vehicle's panel to let the driver know when the system is about to intervene.

    d. Before the system takes control, the system must first make sure that the user did not intentionally try to leave the lane.

    e. Turning your turn signal on signals you intend to switch lanes and will not cause alert.

3. The system will have a lane centering system and lane keeping system.

a. While active, the Lane Centering System must use the Path prediction Subsystem to accurately calculate if the car is centered in the lane or not.

b. In a lane that is not linear, there would be an estimation system that predicts and determines the speed, angle, and road curvature.

c. The system will have cameras that will monitor the sides of the vehicle.

d. Images are then sent to processing to ID lane markings.

e. The system's cameras will monitor the front, side, and exterior sides of the vehicle.

f. The system shall recognize different types of lane markings: solid lines, dashed lines, and double lines. It shall only warn the user when the vehicle's about to cross solid and double lines, or when the vehicle's crossing dashed lines with signals left off.

g. This should occur in a set amount of time or distance so that it can continuously and periodically reevaluate the situation.

4. The system shall continuously monitor the status of hardware components.

   a. When inputs from the hardware are inconsistent or unreliable due to hardware failures or hazardous environmental conditions, LMS shall warn the user and be deactivated.

3.2 Secondary Requirements:

1. The Lane Departure Warning System should be able to gently alert the driver that the vehicle is leaving the lane without a warning that would impede the ability to operate the vehicle.

2. There will be a disclaimer that the LMS is not a substitute for paying attention and driving carefully.

3. The driver will be alerted if the LMS is turned off if it is not able to detect lines.

4. The system can be turned off by the driver.

5. The system will provide brief steering nudges and not aggressive movements.

3.3 Global Invariants:

1. Prevent lane drifting.

2. Alerts driver of drifting.

3. The system's purpose is to prevent accidents.

4. The system shall maintain continuous monitoring of the vehicle, the lane boundary, and surrounding objects under all road and environmental conditions.

5. When the user intervenes, the vehicle shall disregard the system's instructions and behave based on the user's instructions.

6. Never go over 5 mph over the current speed when adjusting

7. Continuously adjust the system to adapt to the current landscape.

3.4 Cybersecurity Requirements:

1. Threat Vectors

    1.a. Unpatched vulnerabilities in the software

    1.b. Malware in the LMS

    1.c. Destruction of the road

    1.d. Destruction of the camera system

    1.e. Weather that can change the environment's appearance

2. Threat Actors

    2.a. Hackers

    2.b. Other drivers

3. Types of cybersecurity vulnerabilities

3.a. If there was a global road system that indicated where the lane markings would be, it could be hacked and the lane markings would change. This would cause the LMS to give incorrect predictions that could result in accidents. One way to prevent this would be to have a very secure system, and rely partially on physical markings.

3.b. Cameras may be obstructed by poor weather such as heavy rain, fog, or snow that will interfere with the LMS's ability to predict location and adjust. Having markers outside of the lane markings would help mitigate this situation.

4 Modeling Requirements

This section presents multiple models to visualize the functionality of the LMS system. Below we will find Use Case Diagrams, a Class Model with a data dictionary describing classes, Sequence Diagrams, and State Diagrams.

4.1 Use Case Diagram

Figure 3 is the use case diagram for LMS. The purpose of the use case diagram is to illustrate the desired observable system behavior. The blue rectangle in the use case diagram in **Figure 3** defines the system boundary. The use cases are enveloped in the blue ovals. The stick figures are outside of the system boundaries and are external actors that are connected to the use cases in which they interact with. The use cases are further described in **Table 1**, which cross reference the requirements in Section 3. The use case diagram shows that the user of the car and LMS can activate the LMS which displays the LMS system status. The system status can also display the system's activity. Detecting the lane markers is also part of the system display since it extends into it.

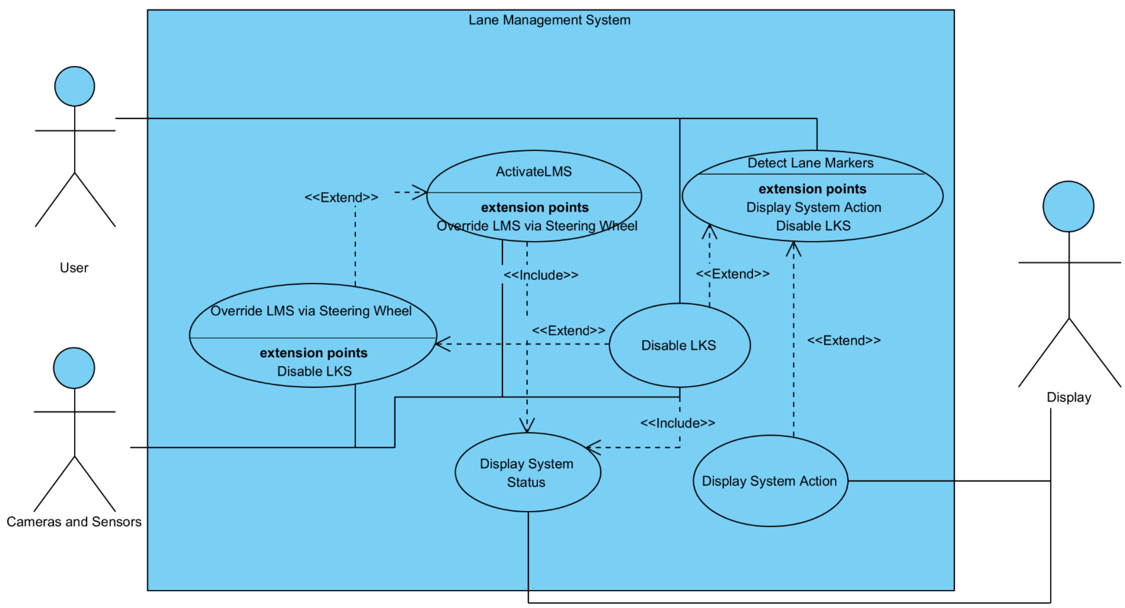

Figure 3: Use case diagram for our lane management system. The boundary is defined by the blue rectangle with a black outline.The use cases are in the ovals and the external actors are outside of the boundary. The external actors interact with the use cases. Users can activate the LMS which then activates the Display System Status. When the car is out of bounds. The LMS will detect lane markers and when the LMS is taking over the car, the steering wheel can be overridden through disabling LKS.

Table 1: Use case descriptions for our lane management system. These describe the use case diagram above and any cross-references for the requirements associated. It also describes the actors and dependencies with other use cases.

Use Case:	***Activate LMS***
Actors:	**Driver**
Description:	**The LMS shall activate automatically at a speed of 35 miles per hour** **While active, the system shall override gently to ensure the vehicle stays within the lanes detected by the sensors**
Type:	**Primary**
Includes:	**Display system status**
Extends:	**N/A**
Cross-refs:	**1a, 1b, 1c, 3a, 3b,**
Use cases:	***Detect Lane Markers***

Use Case:	***Disable LKS***
Actors:	**Driver**
Description:	**The driver shall disable LKS via the GUI or by correcting via the steering wheel.** **LKS shall be disabled when cameras and sensors cannot detect the lane**
Type:	**Primary**
Includes:	**Display system status**
Extends:	**Detect lane markers** **Override LMS via steering wheel**
Cross-refs:	**1d, 1e, 2f**
Use cases:	***Display system status***

Use Case:	***Override LMS via steering wheel***
Actors:	**Driver**
Description:	**The system shall detect the torque needed and apply to the steering wheel to gently steer the car back to the center of the lane**

	When the driver applies torque to the wheel, then the LKS will disable itself
Type:	**Primary**
Includes:	**N/A**
Extends:	**Activate LMS**
Cross-refs:	**1b. 1c. 1e. 2e**
Use cases:	***Disable LKS, Activate LMS***

Use Case:	***Detect lane markers***
Actors:	**Cameras and Sensors**
Description:	**Cameras and Sensors provide the information of lane markers for the system on a frequent basis** **The information provided by the sensors shall be used to predict the given path of the vehicle.**
Type:	**Primary**
Includes:	**N/A**
Extends:	**N/A**
Cross-refs:	**2a, 3c, 3g, 3d, 3b, Secondary Requirement 3**
Use cases:	***Disable LKS, Activate LMS***

Use Case:	***Display System Status***
Actors:	**Driver System**
Description:	**There should be a light on to display if the system is on.** **LKS on then everything has to be on.** **LKS can be off and departure warnings can still be present**
Type:	**Secondary**
Includes:	**N/A**

Extends:	**N/A**
Cross-refs:	**Secondary Requirement 3**
Use cases:	***N/A***

Use Case:	***Display System Action***
Actors:	**System**
Description:	**There shall be warning light in the panel to let the driver know when the system is about to intervene** **The warning light shall display the direction of the system's action** **The system shall warn the driver when the vehicle is about to cross the lane**
Type:	**Primary**
Includes:	**N/A**
Extends:	**N/A**
Cross-refs:	**2b, 2c, 2d, 2g, 3g, Secondary Requirement 1**
Use cases:	***Activate LMS***

4.2 Domain Model

Figure 4 below shows an object-oriented model, or domain model, for the Lane Management System. It uses UML class diagram notation for its corresponding operations and attributes. The boxes describe the different systems that make up the overall Lane Management System. For example the CameraSystem box is associated with the Lane Management System and has attributes which find the distance to the lane and if the lane is present. The line with a diamond on the end signifies aggregation, which shows that one of the classes is part of another. Relationships can be shown with a single line and specifies connections between their instances.

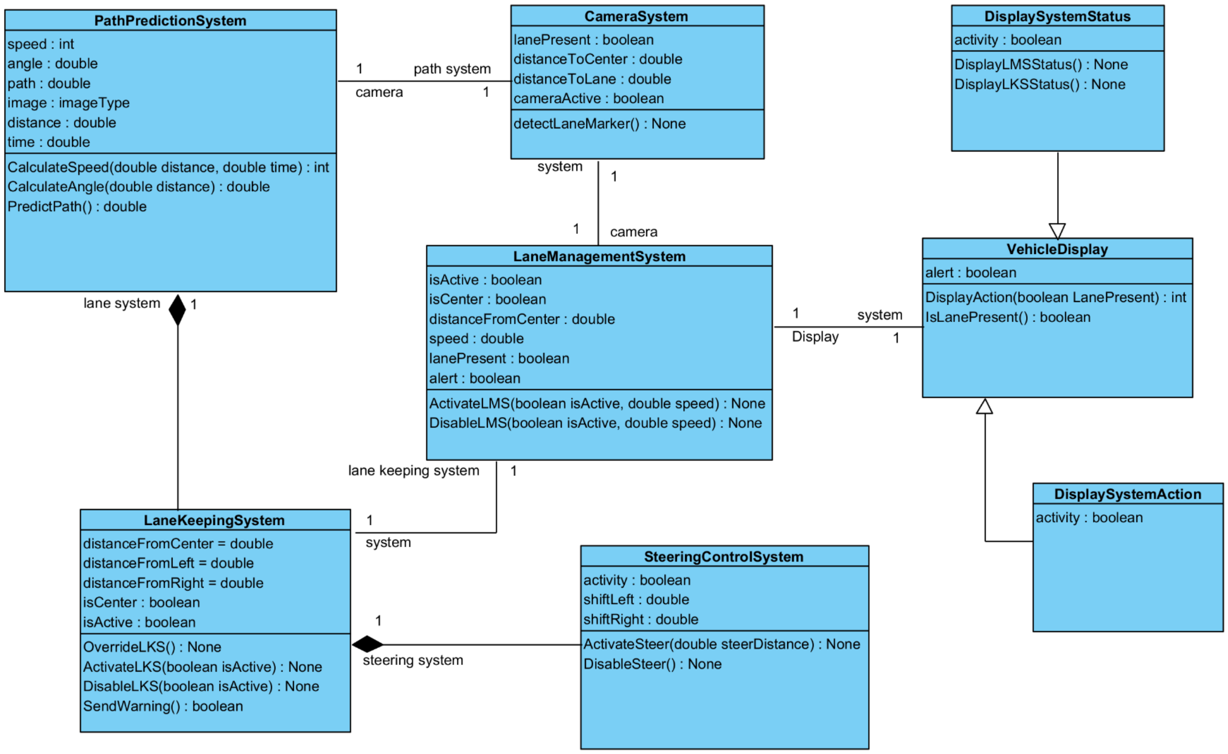

Figure 4: The figure shows a high level domain model for the Lane Management System.

Table 2: Data Dictionary describes the attributes and operations of the classes in the domain model

<table>
<tr><td>Class</td><td colspan="2">SteeringControlSystem</td></tr>
<tr><td rowspan="6">Name</td><td colspan="2">Description (responsibilities) The system shall help steer the car back into the center</td></tr>
<tr><td colspan="2">Export control (public: yes/no) No</td></tr>
<tr><td rowspan="3">Relationships</td><td>Associations: LaneKeepingSystem</td></tr>
<tr><td>Aggregations:</td></tr>
<tr><td>Generalization:</td></tr>
<tr><td colspan="2">List of attributes and their primitive types
activity = boolean
shiftLeft = double</td></tr>
</table>

	shiftRight = double
	List of operations (include parameters and results) ActivateSteer() return None DisableSteer() return None

<table>
<tr><td>Class</td><td colspan="2">Camera System</td></tr>
<tr><td rowspan="7">Name</td><td colspan="2">Description (responsibilities) The camera system shall detect the lanes present and send data to the path prediction system.</td></tr>
<tr><td colspan="2">Export control (public: yes/no) No</td></tr>
<tr><td rowspan="3">Relationships</td><td>Associations: LaneManagementSystem, PathPredictionSystem</td></tr>
<tr><td>Aggregations:</td></tr>
<tr><td>Generalization:</td></tr>
<tr><td colspan="2">List of attributes and their primitive types
lanePresent = boolean
distanceToCenter = double
distanceToLane = double
cameraActive = boolean</td></tr>
<tr><td colspan="2">List of operations (include parameters and results)
detectLaneMarker() return boolean</td></tr>
</table>

<table>
<tr><td>Class</td><td colspan="2">Path Prediction System</td></tr>
<tr><td rowspan="3">Name</td><td colspan="2">Description (responsibilities)</td></tr>
<tr><td colspan="2">Export control (public: yes/no) no</td></tr>
<tr><td>Relationships</td><td>Associations: CameraSystem</td></tr>
</table>

		Aggregations: LaneKeepingSystem
		Generalization:
	List of attributes and their primitive types speed = int angle = double path = double image = imageType distance = double time = double	
	List of operations (include parameters and results) CalculateSpeed(distance, time) return int CalculateAngle() return double PredictPath() return double	

Class	VehicleDisplay	
Name	***Description (responsibilities)*** The vehicle display alerts the driver of the current system's status	
	Export control (public: yes/no) yes	
	Relationships	Associations: LaneManagementSystem
		Aggregations:
		Generalization: DisplaySystemStatus, DisplaySystemStatus
	List of attributes and their primitive types alert = boolean	
	List of operations (include parameters and results) DisplayAction(boolean LanePresent) return int IsLanePresent() return boolean	

<table>
<tr><td>Class</td><td colspan="2">Display System Status</td></tr>
<tr><td rowspan="7">Name</td><td colspan="2">Description (responsibilities) It displays whether the system is active or not</td></tr>
<tr><td colspan="2">Export control (public: yes/no) no</td></tr>
<tr><td rowspan="3">Relationships</td><td>Associations:</td></tr>
<tr><td>Aggregations:</td></tr>
<tr><td>Generalization:</td></tr>
<tr><td colspan="2">List of attributes and their primitive types
activity = boolean</td></tr>
<tr><td colspan="2">List of operations (include parameters and results)
DisplayLMSStatus() return None
DisplayLKSStatus() return None</td></tr>
</table>

<table>
<tr><td>Class</td><td colspan="2">LaneKeepingSystem</td></tr>
<tr><td rowspan="6">Name</td><td colspan="2">Description (responsibilities) Keep the car in the center of the lane</td></tr>
<tr><td colspan="2">Export control (public: yes/no) no</td></tr>
<tr><td rowspan="3">Relationships</td><td>Associations: LaneManagementSystem</td></tr>
<tr><td>Aggregations: PathPredictionSystem, SteeringControl</td></tr>
<tr><td>Generalization:</td></tr>
<tr><td colspan="2">List of attributes and their primitive types
distanceFromCenter = double
distanceFromRight = double
distanceFromLeft = double</td></tr>
</table>

	isCenter = boolean isActive = boolean
	List of operations (include parameters and results) OverrideLKS() return None ActivateLKS(boolean isActive) return None DisableLKS(boolean isActive) return None

<table>
<tr><td>Class</td><td colspan="2">LaneManagementSystem</td></tr>
<tr><td rowspan="7">Name</td><td colspan="2">Description (responsibilities) Manages the overall system to ensure the car is in the center through the usage of camera path prediction system, LKS, and vehicle display</td></tr>
<tr><td colspan="2">Export control (public: yes/no) yes</td></tr>
<tr><td rowspan="3">Relationships</td><td>Associations: CameraSystem, VehicleDisplay, LaneKeepingSystem</td></tr>
<tr><td>Aggregations:</td></tr>
<tr><td>Generalization:</td></tr>
<tr><td colspan="2">List of attributes and their primitive types
isActive = boolean
distanceFromCenter = double
isCenter = boolean
speed = double
lanePresent = boolean
distanceToCenter = double
alert = boolean</td></tr>
<tr><td colspan="2">List of operations (include parameters and results)
ActivateLMS(boolean isActive, double speed) return None
DisableLMS(boolean isActive, double speed) return None</td></tr>
</table>

4.3 Sequence Diagrams

These figures below are the sequence diagrams that illustrate how the different parts of the system interact over time. These describe specific scenarios on how the system may react. The diagrams capture normal and abnormal behaviors to illustrate the system's reactions and how the different components interact in these abstract situations. The bodies are the objects, while the dotted lines represent the lifelines from the objects. Interactions between objects are shown through arrows with the mechanism involved in the interaction.

4.3.1 Lane Centering

Figure 5 shows the sequence diagram for when the car is near the lane border and the LMS centers itself back in the line. The path prediction system calculates and updates the path frequently via the UI. When the vehicle is moving towards either the left or the right lane markers, the LKS overrides the steering to center it back through the path prediction system.

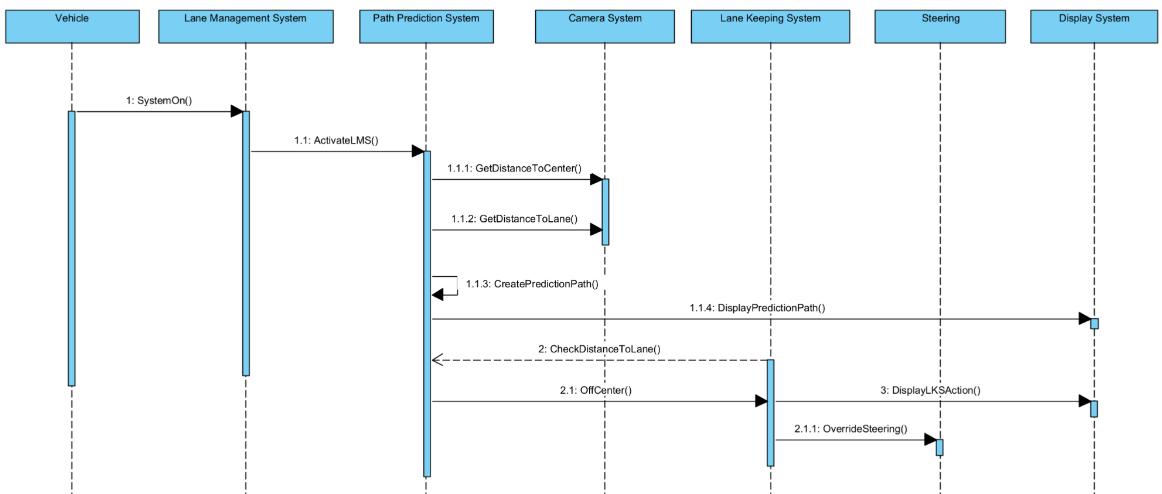

Figure 5: Normal lane centering mechanism scenario. The driver moves near the side of the line where the path prediction system gets information on the distance to the center of the lane, and this allows the system to create a prediction path. The system takes control of the steering wheel and the car is returned to the center.

4.3.2 Switching Lanes

Figure 6 shows the sequence diagram when the car is switching lanes and does not need to be centered. When moving to another lane, the lane management system does not need to keep the car centered. The lane management system needs to see if the lane is being breached and if it is being breached, then this indicates the car is attempting to move lanes. If the lane is breached, the system does not override the steering and the user maintains control.

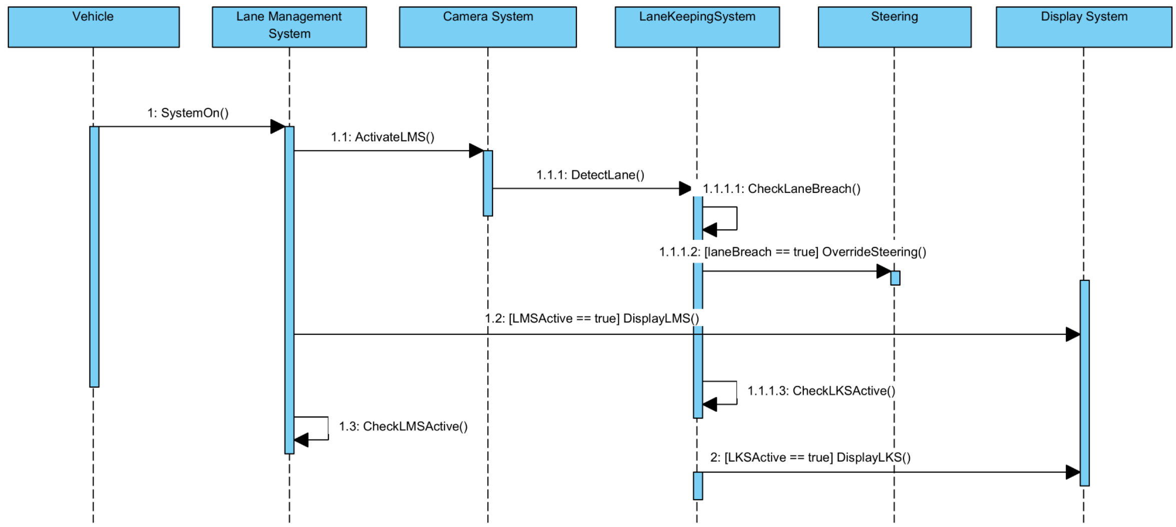

Figure 6: The vehicle is switching lanes and so this means that the LMS is still active and detecting lanes. However, the system checks for a lane breach in the lane keeping system and if this is true, it overrides the steering so that the user maintains control of the steering wheel. It continuously checks the lane keeping system to see if it is true or not when breaching a new lane.

4.3.3 LMS is turned off when the turning signal is on

In **figure 7** the lane management system is turned off when the turning signal is on. The vehicle is attempting to turn and the lane management system checks for a turn signal. If the turn signal is active, then it overrides the lane keeping system. This means that detection of the lane is not needed and the lane keeping system is not active. It also displays the activity of the lane management system, and since there is a turn signal, it displays that the car is turning.

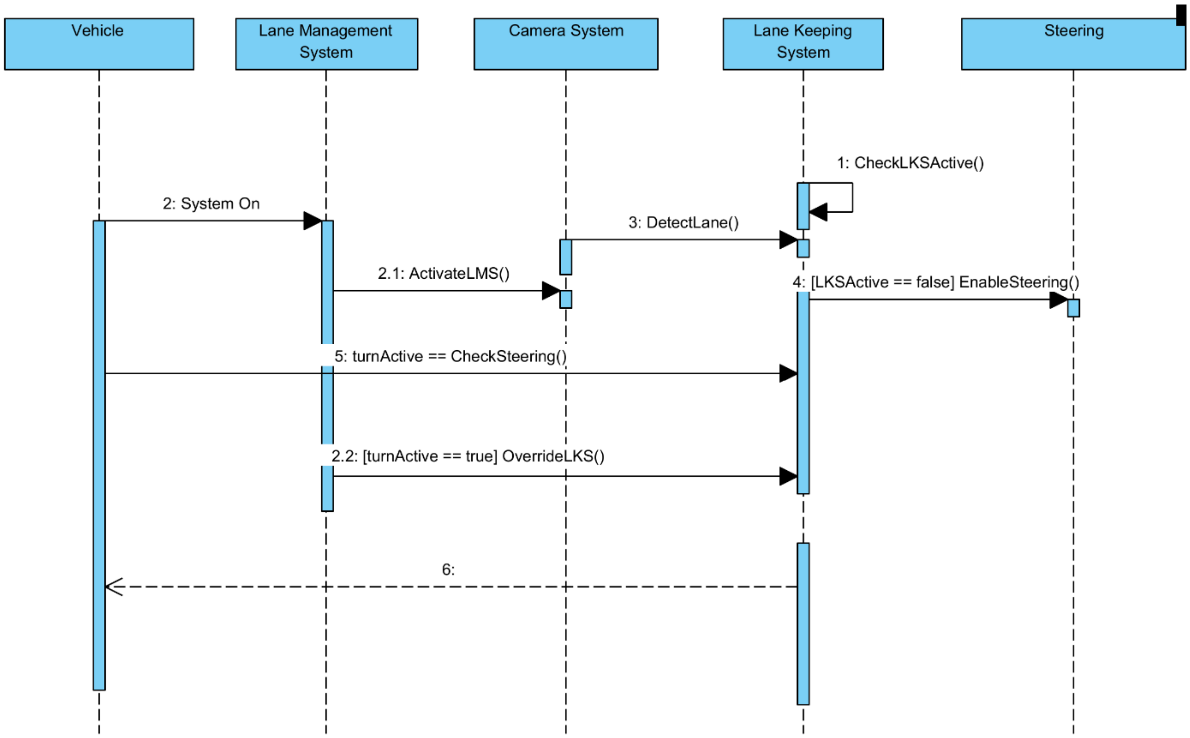

Figure 7: The LMS system is overwritten and does not center when the left or right turn signal is on. When the left or right turn signal is on, the lane keeping system is overwritten and does not allow for the steering to be taken control by the system

4.3.4 Lane is turned off by driver via GUI

In **figure 8** the lane management system is turned off by the user interface by the user. The driver turns off the lane management system and the display system will receive a warning whenever the path prediction system detects that the car is getting too close to the lane's border. It also checks whether the car is leaving the lane, and if it is, then it will alert the driver.

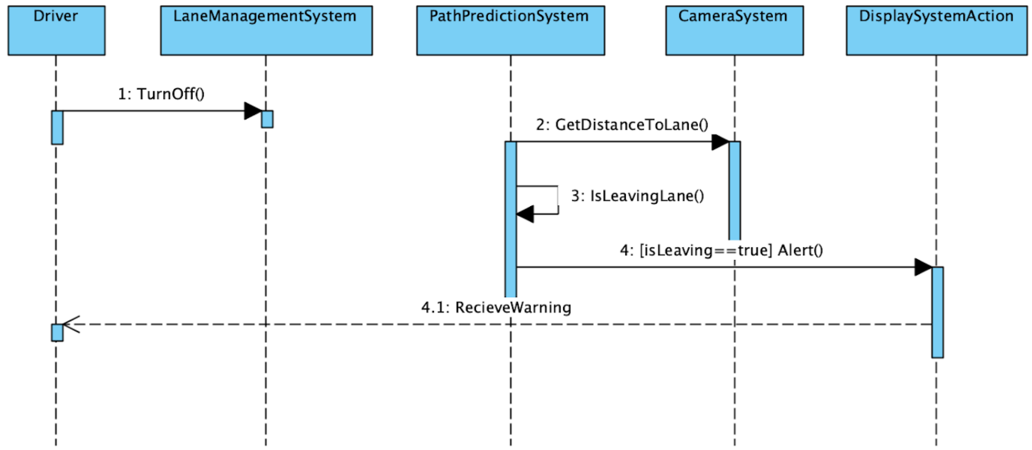

Figure 8: The driver can turn off LMS via the user interface. When LMS is turned off, lane departure warning is still on and displays warning if the vehicle leaves the lane.

4.3.5 LMS is overwritten by steering handle by user

Figure 9's sequence of events is when the lane management system is overwritten by steering handle by user. The lane management system will detect when the car is getting too close to the edge of the lane. The driver is able to override the lane management system when the lane management system checks for whether the steering is active by the driver. If the steering is active by the driver, it disables the lane keeping system so that the driver can maintain steering.

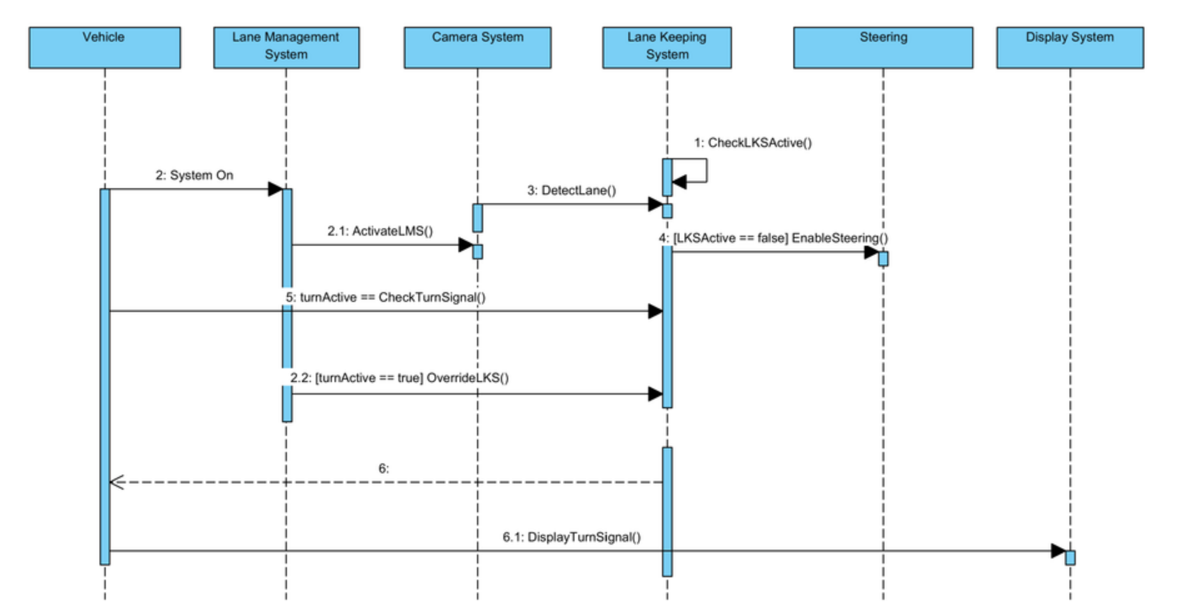

Figure 9: When the user holds onto the steering wheel and personally moves the car back into the center, the LMS system is overwritten and does not take control of the steering wheel. The user can override the system by steering.

4.4 State Diagram

The state diagram section describes how different components of our system move from state to state. In the diagrams, the states are shown with the blue box and the transitions betweens states are denoted with the lines with arrows. The text associated with the transitions show what is causing the state to move and progress. Behavior of the Lane Management System is shown at a high level with the state diagram.

Figure 10 displays the state diagram of the Lane Management System. It starts at the idle state and switches to "Car Leaving Lane" state when the camera and sensor systems detect the lane markers. If the signal is on, the system does nothing. If the signal is off, the system displays a departure warning through the internal UI for the user. If the driver doesn't take any action, another warning is displayed, showing the direction that LKS is about to intervene. LKS is then activated and moves the car back to the lane's center. The system returns to the idle state once LKS has completed its action.

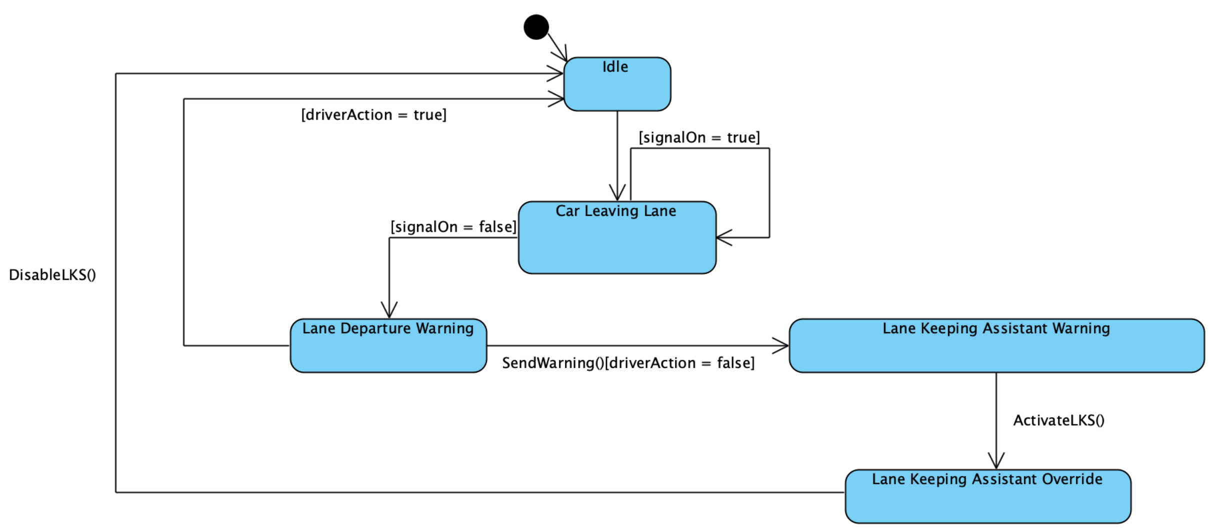

Figure 10: The state diagram shows the different states and conditions of the system and its parts.

5 Prototype

To better understand and investigate the system as a whole as well as analyze edge cases, the team created a prototype to demonstrate the functionalities of the Lane Management System. The prototype provides a mini-world where users can freely experiment with the features that LMS provides. By interacting with the demo program, communication among team members and with customers will be improved.

As the prototype provides a virtual world experience, there is no constriction on how the user interacts with it. This is meant to provide the most realistic experience for the customers and allow the team to test the system in a wide range of scenarios.

5.1 How to Run Prototype

The prototype is built with Unity, a cross-platform game engine. To reduce the complexity of configuration and building the prototype, the team provides a live prototype located on the team website. Users need access to the Internet to access the prototype.

Alternatively, the prototype can be set up locally on the user's machine. By running locally, the user can change the resolution, adjust graphic settings, and use the prototype without an internet connection. To set up locally, please follow the instructions below:

- Download the prototype source code
  - The prototype code is stored on GitHub. The user can download via the GitHub UI or the console/terminal:
    - `git clone https://github.com/truongdd03/lms.git`
- Install Unity
  - Unity can be installed via its official website.
- Open the project
  - Open Unity and select the LMS prototype
- Build and Run project
  - Select the build icon on the top of the view to run the prototype.

5.2 Sample Scenarios

The prototype provides a constriction-free experience for the users. That said, there are endless possibilities for how the prototype can be used to test the LMS and to improve its functionality. However, at the root of the prototype, there are seven main scenarios:

1. Straight line road
2. Curve road
3. No lane marker
4. Override by driver
5. Unexpected light change due to enter/exit tunnel
6. Unusual lane marker: cones
7. Demonstrate the working system, when there is a change of control back and forth between the driver and LMS

To experience all the scenarios above, please visit the prototype on the team website. This section only analyzes **Scenario 4: Curve road.**

Curve road describes the most common and challenging scenario for lane management systems. In this scenario, the LMS must be able to accurately detect the lane boundaries and keep the vehicle within the lane, even when the road is curving. In **Figure 11**, the vehicle is approaching a curve at the speed of 54 mph. LMS is active since the system is able to detect the lane markers on both sides of the vehicle.

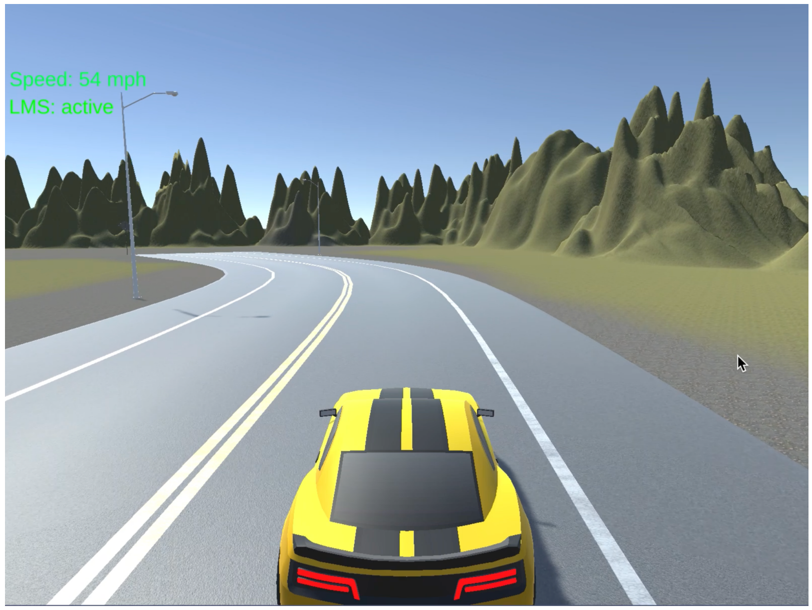

Figure 11: Vehicle approaching a curve

Figure 12 shows that the vehicle is entering the curve. The driver is not controlling the vehicle at the time. LMS intervenes with the steering wheel to slightly steer the vehicle to the left. The speed is slightly reduced to ensure the vehicle stays in the lane. The LMS status display was changed from “active” to “<=====”, indicating the direction that the system is steering toward.

Figure 12: Vehicle entering the curve

In **Figure 13**, the vehicle has exited the curve safely without the intervention of the driver. The speed was dropped to 50 mph but the vehicle is in the middle of the road. The LMS display status switched from “<=====” back to “active”, as the system no longer intervenes with the steering wheel. LMS remains active and ready for future road changes.

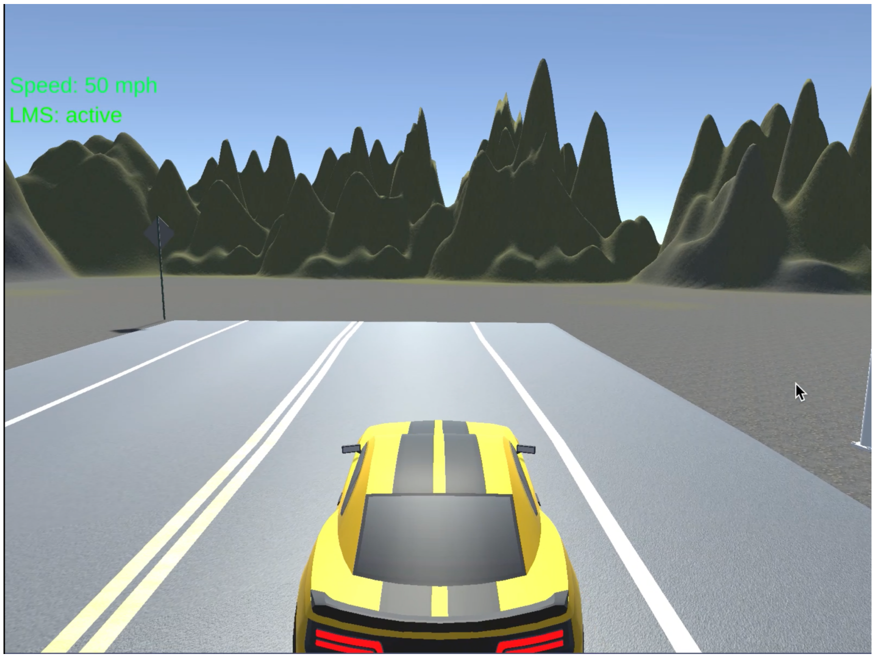

Figure 13: Vehicle exiting the curve

6 References

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[2] *Head-on Crashes - Safety.Fhwa.Dot.Gov*, U.S. Department of Transportation, Federal Highway Administration, safety.fhwa.dot.gov/roadway_dept/strat_approach/brochure/docs/FHWA-SA-21-025_Head_On_Crashes.pdf. Accessed 8 Nov. 2023.

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7 Point of Contact

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