Software Requirements Specification (SRS)

Project LMS

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1 Introduction

The LMS or Lane Management System is a system that will improve the safety of vehicles by giving the driver a safety measure when driving on the road. This document is organized into several sections, each with dedicated sub-sections to help visualize and make the LMS system safe and operable. It begins with the purpose of the SRS and identifies the audience. Then the Scope section outlines the main objectives, key features, and limitations of the LMS software. The Definitions, Acronyms, and Abbreviations section will then clarify the terms used throughout the document. An Overall Description of the LMS which will cover its context, functionalities, constraints, assumptions, and dependencies. The Specific Requirements section details both functional and non-functional requirements needed for proper system operation. In the Modeling Requirements section, there will be graphical representations of the system's structure and behavior. Finally, a Prototype section that will be to test and validate the LMS system.

1.1 Purpose

The purpose of this Software Requirements Specification document is to provide a detailed description of the requirements for the Lane Management System. This document aims to provide software functionality, operational constraints, and performance criteria to align with our customers' needs. To further specify, our intended audience is our customer, Mr. Ayush Agrawal.

1.2 Scope

The Lane Management System (LMS) is made to prevent unwanted lane changes or departures, enhancing safety by reducing the risk of collisions and dangerous driving. LMS is a system with multiple subsystems that consist of the Lane keeping system, Lane Centering System, and Lane Departure Warning System. When using the system, the LMS will notify the driver using visual indications on the dashboard, as well as sound alerts if the driver gets close to or is on the lane markings, LMS will also help the vehicle back into its lane if it goes over the lane markings. The LMS will not be used to detect objects in the lane beside the vehicle, or objects in front of the vehicle. For a higher-level perspective, the LMS will use the camera to detect a lane beside the vehicle on the road, then the system will calculate the distance the lane marking is from the vehicle. If the driver decides to go too close to the lane markings, then the Lane Centering System will go off and alert the driver that the vehicle needs to be adjusted, if the driver ignores the notification and the vehicle goes too far over the lane markings the Lane Keeping System will activate and the system will provide torque on the steering wheel. If there is a curve the LKS will also help control the speed of the vehicle to allow for proper traction.

1.3 Definitions, acronyms, and abbreviations

Term	Definition
LMS	Lane Management System is the name of the overall system being built, which is a driver assistance system that can include a variety of functions starting with the simplest passive LMS that can detect the lanes and compute the relative position of the vehicle to the most complex active LMS, which can take over control from the driver to position the vehicle within a lane.
LDWS	Lane Departure Warning System issues warnings to the driver when the vehicle leaves a lane.
LCS	Lane Centering System, allows the vehicle to track lane positioning on a given roadway.
LKS	Lane Keeping System is an enhancement to LDWS, where the system could intervene and try to send commands to steer and adjust the position of the vehicle.
Camera Sensing Subsystem	Captures images on the sides of the vehicle and sends them over to the image processing unit for lane marker detection

Image Processing Subsystem	Processes the raw images coming from the camera and identifies the lane marker
Vehicle State Estimation system	A set of sensors that would periodically determine the speed, steering angle, and road curvature
Path prediction Subsystem	A software subsystem receives information from the Image Processing Subsystem and Vehicle State Estimation system and tries to predict the path of the vehicle to detect, warn and possibly correct any potential lane violations and avoid disabling of LMS.
User Interface system	The driver and LMS exchange control and data information through this system.
Supervisory Control Systems	Controls all the other subsystems, decides when to enable and disable other subsystems, and possibly provides diagnostic information.
Driver	The vehicle operator that will be using the LMS system in the vehicle.
UI	User Interface, Where the user and a computer system can interact.

1.4 Organization

For further sections the SRS will contain the overall description, giving a higher-level overview of the LMS. Next will be the specific requirements, listing detailed functional and non-functional requirements. Then there will be modeling requirements, which will define different models. Then the prototype of our current LMS.

SRS Structure:

2 Overall Description

This section, and the following subsections, will describe how the LMS functions. To start, the context and constraints of the system are explored in Section 2.1. Section 2.2 provides an overview and explanation of the system's functionality. Section 2.3 discusses the characteristics of the users of the LMS, things such as background, skill, and general expertise. A more in-depth description of the constraints is discussed in Section 2.4. Any assumptions made about hardware, software, the environment, and user interactions with the system are covered in Section 2.5. Finally, any feature determined to be out of scope and/or to be implemented into future versions/releases of the system is discussed in Section 2.6.

2.1 Product Perspective

The LMS is a system that works with the driver of a vehicle to assist with lane keeping and lane centering. The system works to correct movements of a vehicle that has drifted out of the center of a lane or out of a lane that it was previously in without the proper use of a turn signal or indicator. Further, it works with the user by alerting them via audible, visual, and textile alerts and notifications when it detects that the vehicle is beginning to drift from the center of its lane or into another lane.

The primary interface utilized by the user when interacting with the system is the dashboard and center console as this is where a lot of the information communicated by the LMS is stored. On the dashboard, the user receives alerts and notifications from the

LMS. The user can also customize the functionality and sensitivity of LMS through the center console.

For the LMS to function, the vehicle needs to be equipped with several different pieces of software. Most importantly, a camera for image capturing and a computer to process the images, determine the conditions of the road, compute the appropriate course of action, communicate with other systems onboard the vehicle, and control the subsystems of the LMS.

Each subsystem that the LMS is made up of will require software that allows it to function. This will involve system-specific operations as well as general control structures such as activation and deactivation processes. There will also need to be a software or set of software that allows for the communication between the LMS subsystems and other systems and controls on the vehicle such as the steering wheel, the throttle control, and the dashboard.

Finally, memory is a large constraint on the LMS. The size and availability of the vehicle’s memory places a large constraint on how much memory the LMS can use which can make developing the system difficult.

2.2 Product Functions

The system is made up of several subsystems that communicate with each other for the entire system to properly function. To start, there is a Camera Subsystem that takes pictures of the road. Those pictures are then fed to the Image Processing Subsystem which takes that raw picture data and determines whether there are visible lane markings on the road. Simultaneously, the Vehicle State Estimation System is working with the vehicle's state data. Information such as speed and GPS data is obtained by this unit and fed to the Path Prediction Subsystem along with the result from the Image Processing Subsystem.

From there, the Path Prediction System estimates an appropriate path of the vehicle based on the image data fed to it by the Image Processing Subsystem and the Vehicle’s state information provided by the Vehicle Estimation System. From there, the Path Prediction System decides whether to correct the vehicle's movement or push alerts to the user. If a notification or alert needs to be sent to the user, the Path Prediction System sends that information to the User Interface System which then communicates with the dashboard (if the alert is visual and audible) and/or the steering wheel (if the alert is haptic).

The final subsystem required for the LMS to function is a Supervisory Control Subsystem. This subsystem is responsible for controlling the other previously mentioned subsystems. It is continuously communicating with the other subsystems and is waiting for information that suggests whether a subsystem or set of subsystems needs to be turned on or off. It is also partially responsible for error handling.

2.3 User Characteristics

It is expected that the user is legally licensed to drive. It is also expected that the user can interact with the alerts, notifications, and other features of the LMS in a safe and responsible manner. Finally, it is expected that the user operates the vehicle in a safe and responsible manner and operates the vehicle according to state and federal laws where applicable.

2.4 Constraints

Since the LMS interacts with and controls safety-critical systems such as the throttle and the steering wheel, the system needs to have a certain set of constraints that ensures the safety of the user and other vehicles, drivers, passengers, and pedestrians on and around the road.

To start, the LMS will not function or be active at any speeds under 35 mph.

To control the movement of the vehicle, when correcting the vehicle's movement in the event of something such as an unintentional lane departure for example, the LMS needs to interact with and control the steering wheel. This is done in the form of applying a limited amount of torque to the steering wheel. However, the LMS must not completely control or guide the vehicle along the road as if the system was driving the vehicle itself. So, if the user applies a higher level of torque to the wheel compared to that of the torque being applied by the LMS, the LMS should stop applying torque to the steering wheel and relinquish control of the vehicle to the user.

In combination with controlling the steering of the vehicle for a few moments, (only through corrective actions), the LMS must also have a limited amount of control over the throttle of the vehicle. Control is necessary only when the vehicle is being corrected along a curve as an increase or decrease in speed depending on the bank angle of the curve is required to maintain the speed at which the driver entered the curve. However, due to the safety-critical nature of this control, if the driver applies the brakes, the LMS needs to relinquish its control over the throttle to the user. The throttle must only be used by the LMS to maintain speed while correcting vehicle movement.

The system also needs a set of properly working cameras. A lack of functioning cameras can create dangerous situations for the user and other drivers and vehicles on the road. Due to this, if the LMS detects that the cameras are not working, the LMS should be deactivated. Along with this, if the LMS subsystems determine that the Image Processor and/or the Vehicle State Estimation System are not working, the LMS should deactivate as well as attempt to correct the vehicle in this hypothetical state creates incredibly dangerous situations in which loss of life, injury, or damage to property could occur.

One final constraint to consider is the speed of alerts and notifications being sent to the user. These alerts need to be quick enough for the user to correct for the events the LMS is warning the user about.

2.5 Assumptions and Dependencies

There currently exists a wide variety of assumptions and dependencies placed on the vehicle, hardware, software, environment, and user interactions and capabilities for LMS to function properly.

To start, it is assumed that the vehicle has a properly functioning steering wheel, throttle and throttle control system, and dashboard with working visual and audio interfaces.

It is also assumed that there is enough space available for the LMS to be implemented in full for its base functionality. On top of this, it is assumed that the systems that control the communication between the dashboard, throttle control, and steering wheel function properly.

For the LMS to function, it is assumed that the road the vehicle is traveling on has clear lane markings that are clear and visible to the cameras and can be derived from the Image Processing Subsystem.

It is assumed that the user safely and appropriately operates the vehicle. It is also assumed that the user knows how to operate the vehicle properly and is legally licensed to drive. Finally, users are assumed to properly interact with the LMS and appropriately react to vehicle corrections, alerts, and notifications.

2.6 Apporportioning of Requirements

Currently, out-of-scope operations include obstacle detection and avoidance and blindspot detection and avoidance.

The LMS, at its current state, is not responsible for actively detecting and avoiding any obstacles in front of or around the vehicle while active. The user is still responsible for paying attention on the road and operating their vehicle safely.

The LMS is also not responsible for blindspot detection and avoidance. If the user were to signal that they were merging into another lane, (actions that comply with the requirements of the LMS for it to properly function), and if another vehicle was in the user's blindspot, the LMS is not responsible for alerting the driver of this vehicle or preventing a potential collision with this vehicle. The user is responsible for being aware of the vehicles around their own and vehicles that could potentially be and/or vehicles that are currently in their blind spot.

These features may be explored in future iterations of the Lane Management System, however, at this time this seems unlikely.

3 Specific Requirements

1. Functional requirements
   - 1.1. The system shall turn on when the vehicle is in forward gear and the LMS is enabled by the driver.

1.2. The system shall be enabled once the vehicle is going 35 mph or more and the lanes are detected for 1 second using the camera sensing and image processing subsystems.
1.3. The system shall always be able to be overridden by the driver at any time by applying more torque to the wheel than the system.
    1.3.1. If this is detected the system will deactivate until the driver is no longer applying any torque to the wheel.
1.4. The system will use the supervisory control systems to report to the driver if any subsystem is not working, in which case the system will terminate.
1.5. The system shall use the camera sensing and image processing subsystems to detect the lane markings and relative distance to the vehicle for usage in calculating the necessary torque to apply.
    1.5.1. Apply torque once the lane border has been detected to have been crossed.
1.6. The system shall use the Vehicle State Estimation system to monitor:
    1.6.1. Speed of Car
    1.6.2. Steering Angle of Vehicle
    1.6.3. Road Curvature
1.7. The system shall turn off if the lane markings become inconsistent or undetectable.
    1.7.1. If the system is turned off, the system shall alert the driver by a vibration of the steering wheel, as well as an audible beep with a notification on the dashboard that the LMS has been deactivated.
1.8. The system will provide audible and visual warnings to the driver when it detects the vehicle moving out of its lane.
1.9. The system should be able to detect several different lane markings:
    1.9.1. Solid Yellow
    1.9.2. Solid Double Yellow
    1.9.3. Dashed Yellow
    1.9.4. Solid Yellow & Dashed Yellow
    1.9.5. Solid White
    1.9.6. Dashed White
1.10. The system shall ignore all boundaries on the same side as an active blinker.
    1.10.1. Once the blinker is deactivated, the system will reevaluate the lane markings before turning back on if they are detected.
1.11. The system shall still give alerts even when the driver is purposely crossing a lane marking without a blinker.
1.12. The system shall vibrate the steering wheel to alert the driver if the system is attempting to apply more torque than the driver in the opposite direction.
1.13. The system will monitor the driver’s engagement with the steering wheel and will provide alerts when they are off (detection is 2 seconds)

2. Non-Functional Requirements
    2.1. Do not annoy the driver with too many unnecessary alerts
    2.2. Have a clear indication of the LMS being active on the dashboard

2.3. Display proximity to boundaries on the dashboard visually
2.4. Do not send false signals
2.5. System sensitivity should be able to be customizable at the user's discretion
    2.5.1. The user can decide how much torque they wish the system to apply when lane-keeping
    2.5.2. The user can decide how to be alerted when the warning system detects the vehicle leaving its lane. They cannot turn off any essential alerts, however.

3. Invariant Requirements
    3.1. The system should always be prepared to relinquish control to the driver
    3.2. The system shall be enabled only when driving 35+ miles per hour.
    3.3. The system will not activate if a double yellow lane marking is detected to be on the right side of the vehicle. (Regional setting)
    3.4. The system shall not work if it is turned off.
    3.5. The vehicle must be stable and within the boundaries of the lane.
        3.5.1. The system shall stop applying steering torque on the steering wheel when the driver is applying more force to turn or change lanes.
    3.6. The vehicle must have functional blinkers for the system to be enabled.

4. Cybersecurity requirements
    4.1. The most likely pathway for an attack is through the system updates, which happen over the air during vehicle updates from satellites. There is no internet or Bluetooth connectivity.
    4.2. The most likely threat actors for this system are white-hat hackers and cyberterrorists.
        4.2.1. White-hat hackers could be employed by the companies creating or implementing the software to close up any security breaches in the software.
        4.2.2. Cyberterrorists could be motivated to cause car accidents, by feeding the system false data and causing the system to make the vehicle swerve.
    4.3. The vulnerabilities in the system lie mainly in the camera and image processing subsystems.
        4.3.1. Images could be fabricated and sent to the camera subsystem instead of the intended pictures causing the vehicle to incorrectly detect the lane markings
        4.3.2. Images could be modified going from the camera subsystem to the image processing subsystem to create a similar effect.
        4.3.3. These can be prevented by adding a verification method to the images to ensure that they were sent internally and not from outside sources.

4 Modeling Requirements

This section contains a variety of models to provide a visual and high-level overview of the proposed Lane Management System alongside its sub-systems and functionality.

4.1 Use Case Diagram

Figure 1 illustrates the relevant actors outside of the system alongside the interactions these actors have in relation to the system. With this, the interactions between the subsystems themselves are also depicted. The blue rectangle indicates the system boundary and all of the systems and functions within it. Outside of the blue rectangle are the actors or external entities the system interacts with or responds to. Following this is **Table 1** which lists a variety of use case descriptions for the system.

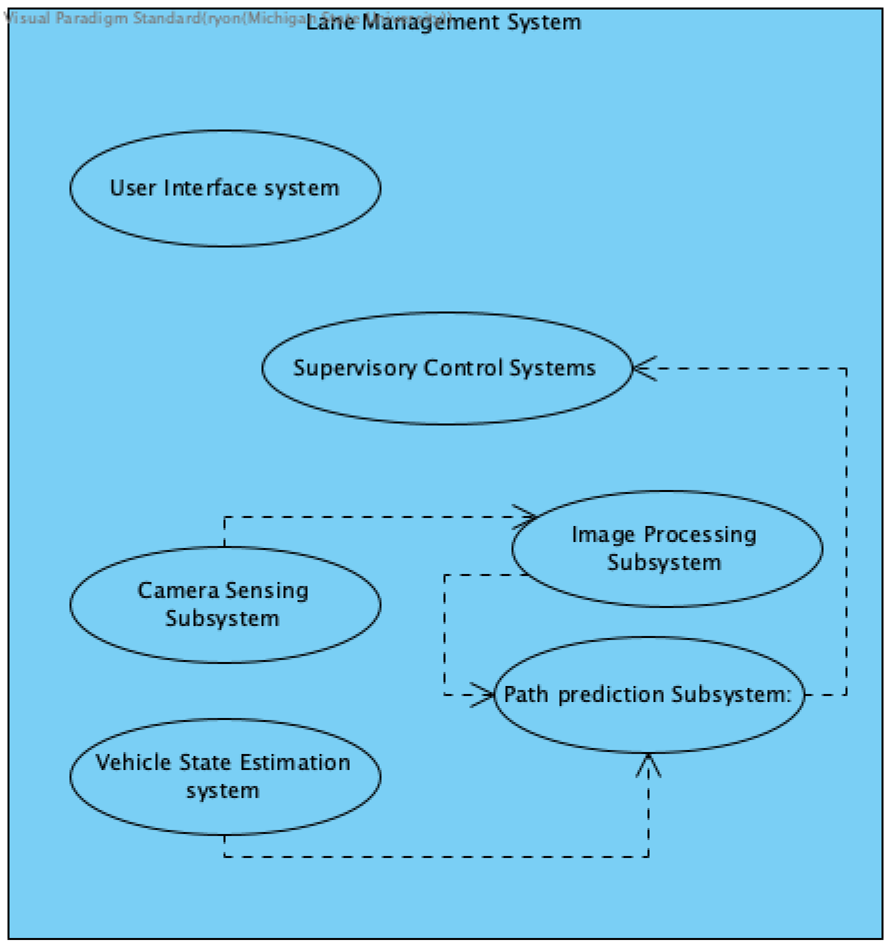


Figure 1: Use Case Diagram for proposed LMS System.

Table 1: Use Case Descriptions for the proposed LMS system.

Use Case	Activate Lane Management System
Actors	User
Description	**The system shall turn on when the vehicle is in forward gear and the LMS is enabled by the driver.**
Type	Primary

Use Case	Enable Lane Management System
Actors	User
Description	**The system shall be enabled once the vehicle is going 35 mph or more and the lanes are detected for 1 second using the camera sensing and image processing subsystems.**
Type	Primary

Use Case	Disable Lane Management System
Actors	Lane Management System
Description	**The system shall turn off if the lane markings become inconsistent or undetectable.**
Type	Primary

Use Case	Sensor Sanity Check
Actors	LDWS
Description	In this use case, the LDWS performs a sanity check on its sensors to verify that they are working properly and that all data is reliable.
Type	Primary

Use Case	System On

Actors	Vehicle Estimation System
Description	In this use case, the Vehicle Estimation System tracks the current speed of the via sensors and initializes the system startup process when the vehicle's speed exceeds 35 miles per hour.
Type	Primary

Use Case	Valid Lane Markings
Actors	Camera Sensing Subsystem, Image Processing Subsystem
Description	In this use case, the Camera Sensing Subsystem and the Image Processing Subsystem capture and validate the lane markings on the road.
Type	Primary

4.2 Class Diagram

Figure 2: depicts the class diagram for the proposed LMS system. The purpose of the diagram is to provide a high-level overview of the system. More specifically, the objects that make up the system and the relationships between these objects. Each class/object or system is represented by a blue rectangle. Connections with diamonds on the end indicate aggregation or composition. Closed diamonds indicate composition, meaning that…. While open diamonds indicate aggregation meaning that the class furthest from the diamond is part of the class nearest to the diamond. Connections with triangles on the end indicate that the class nearest to the triangle will utilize functions from the class furthest from the triangle.

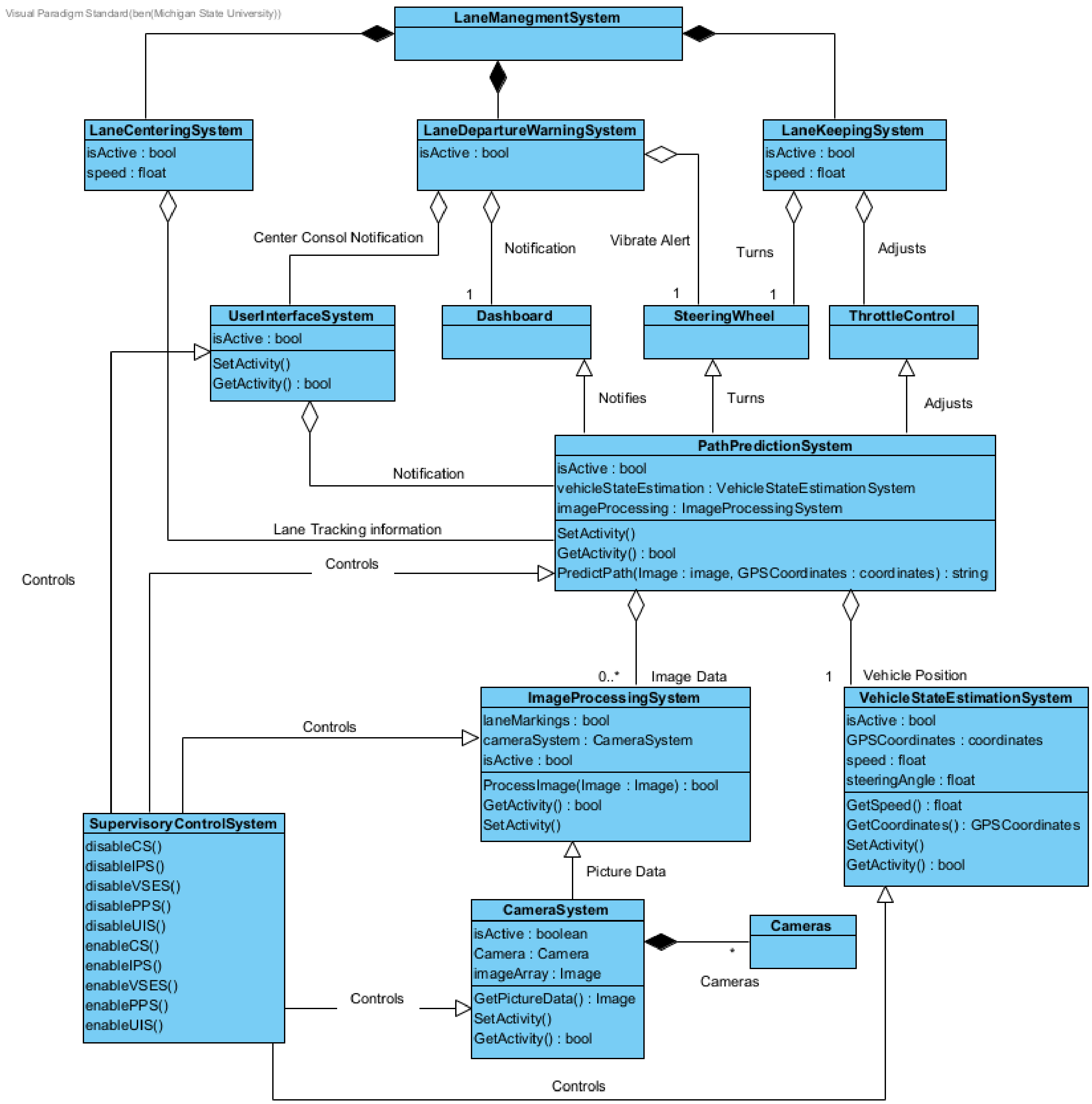


Figure 2: Class diagram for proposed LMS System

Class Diagram Dictionary:

LDWS

Vehicle Estimation System:

Member Variables:

- Speed
- Road Curvature
- Steering Angle

Methods:

- GetSpeed( )
- GetRoadCurvature( )
- GetSteeringAngle( )
- SensorSanityCheck( )
- SendVehicleData( )

Camera Sensing Subsystem

Member Variables:

- DistanceFromMarking
- Marking

Methods:

- GetDistanceFromMarking( )
- ValidLaneMarkings( )
- CaptureMarkings( )
- SendCapturedMarking( )
- ReceiveAccuracyRate( )
- UpdateData( )
- SensorSanityCheck( )

Image Processing Subsystem:

Member Variables:

- AccuracyRate

Methods:

- GetAccuracyRate( )
- AnalyzeSentCapturedMarkings( )
- CalculateAccuracyRate( )
- SendAccuracyRate( )

Path Prediction Subsystem:

Member Variables:

- PredictPath

Methods:
- GetPredictedPath( )
- ReceiveAccuracyRate( )
- ReceiveVehicleData( )
- PredictPath( )
- UpdatePathCorrection( )
- SendWarning( )

User Interface System:

Member Variables:
- System
- Warning

Methods:
- SystemOn( )
- FailState( )
- ReadyState( )
- CarData( )
- DisplayWarning( )
- DisplayData( )

Class Relationships:

LDWS

Vehicle Estimation System <> —--------------------------------> Camera Sensing Subsystem
Vehicle Estimation System <> —--------------------------------> Path Prediction Subsystem
Vehicle Estimation System <> —--------------------------------> User Interface System

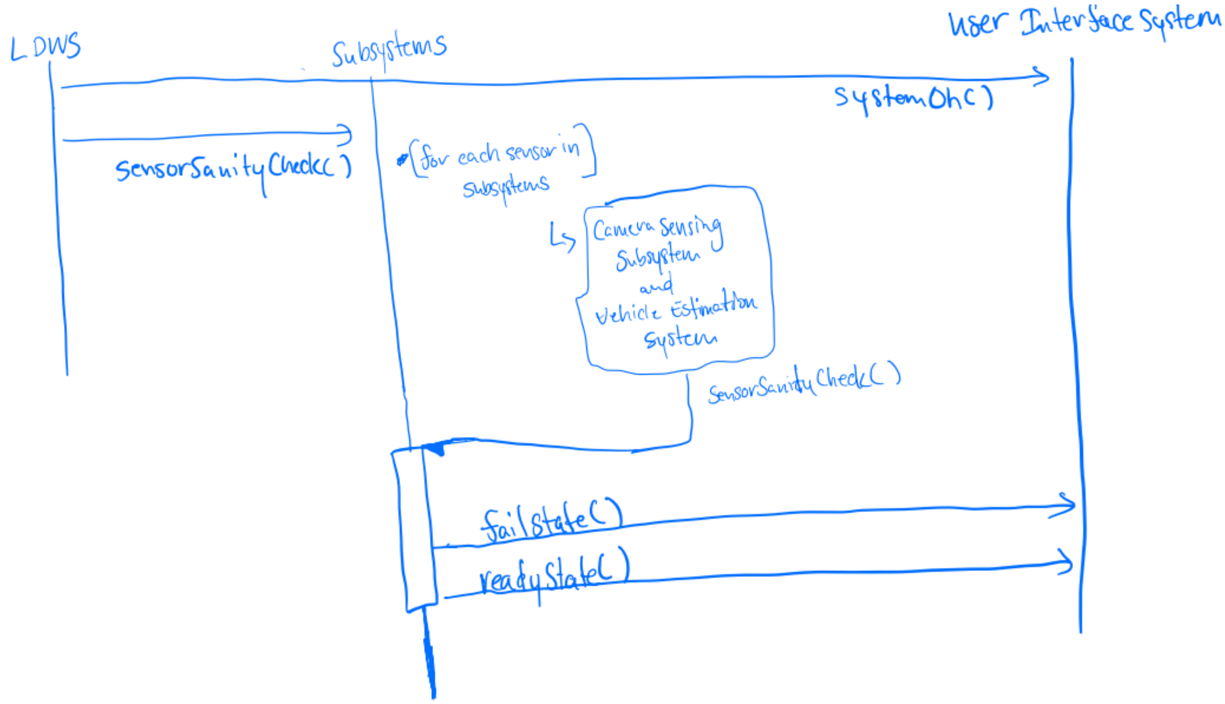
Camera Sensing Subsystem <> —-------------------------------> Image Processing Subsystem
Camera Sensing Subsystem <> —-------------------------------> User Interface System
Image Processing Subsystem <> —-----------------------------> Path Prediction Subsystem

4.3 Representative Scenarios of System

Scenario: Sensor Sanity check

English description:

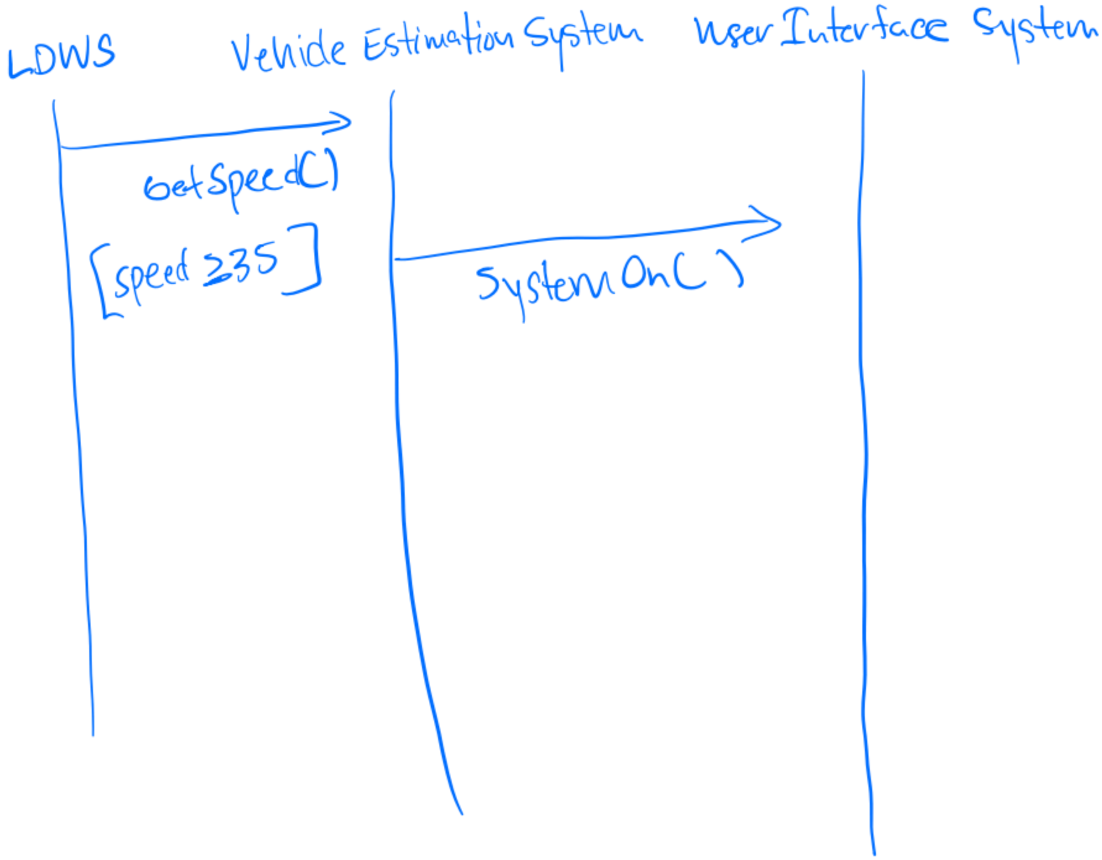
The LDWS performs a system senor sanity check across all of the sensors that are used in the system. If all passes the system will be set to a ready state meaning the sensors respond correctly. If any fail the system will be set to a fail state and will notify the user.



Scenario: System On

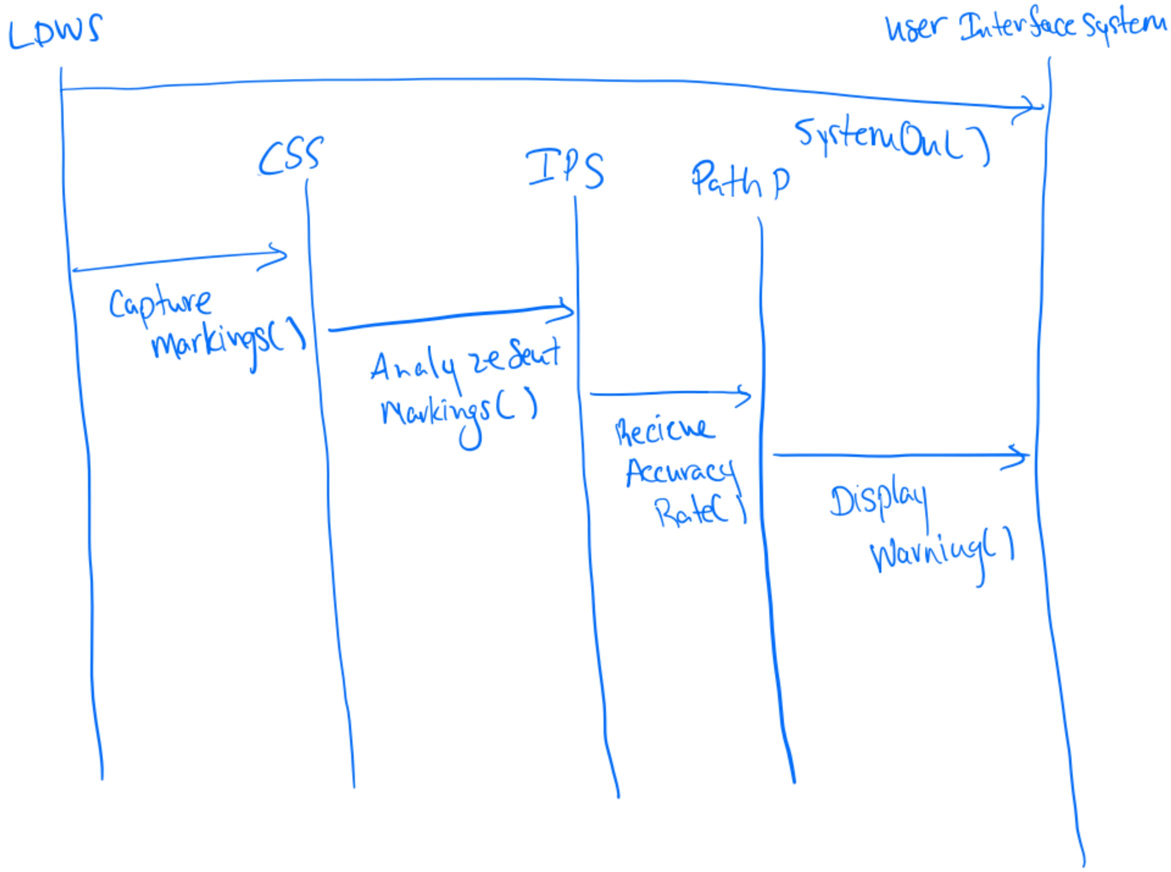
English description:

The LDWS checks if the vehicle speed is at least 35 miles per hour before starting the system.



Scenario: Valid Lane Markings

English description: The Camera Sensing Subsystem and the Image Processing Subsystem capture and validate the lane markings on the road if the markings are not valid the system sends a warning to the user.



4.4 State Diagram

(Disregard for now)

5 Prototype

The prototype associated with this project will demonstrate how the LMS system should function under different scenarios. There will be four scenarios. The first will be the ideal scenario in which the car is going down a straight road at a constant speed. The second will be of a road with non-zero curvature to demonstrate the functionality of the system under more stress. Third will be the failure scenario where lane markings become undetectable or unclear. Lastly, there will be another set of lanes showing the system taking back control from the driver once lanes are detected again.

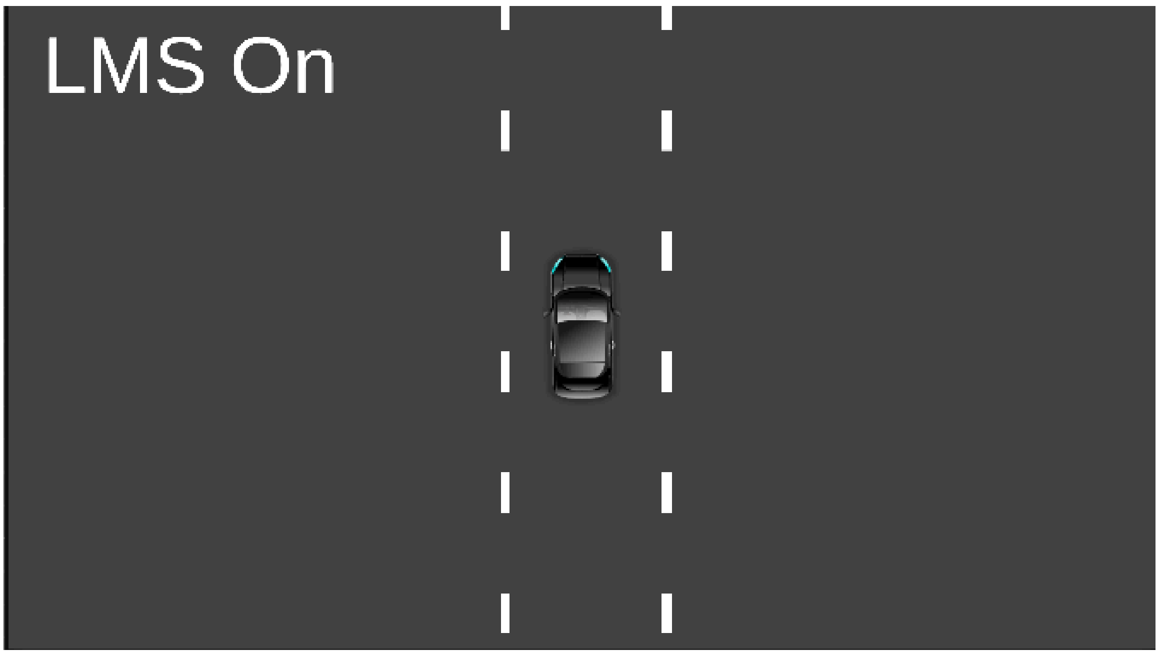
5.1 How to Run Prototype

To run the prototype, follow the link from the project website to be taken to a page with an embedded Unity web player. The controls for the prototype are the

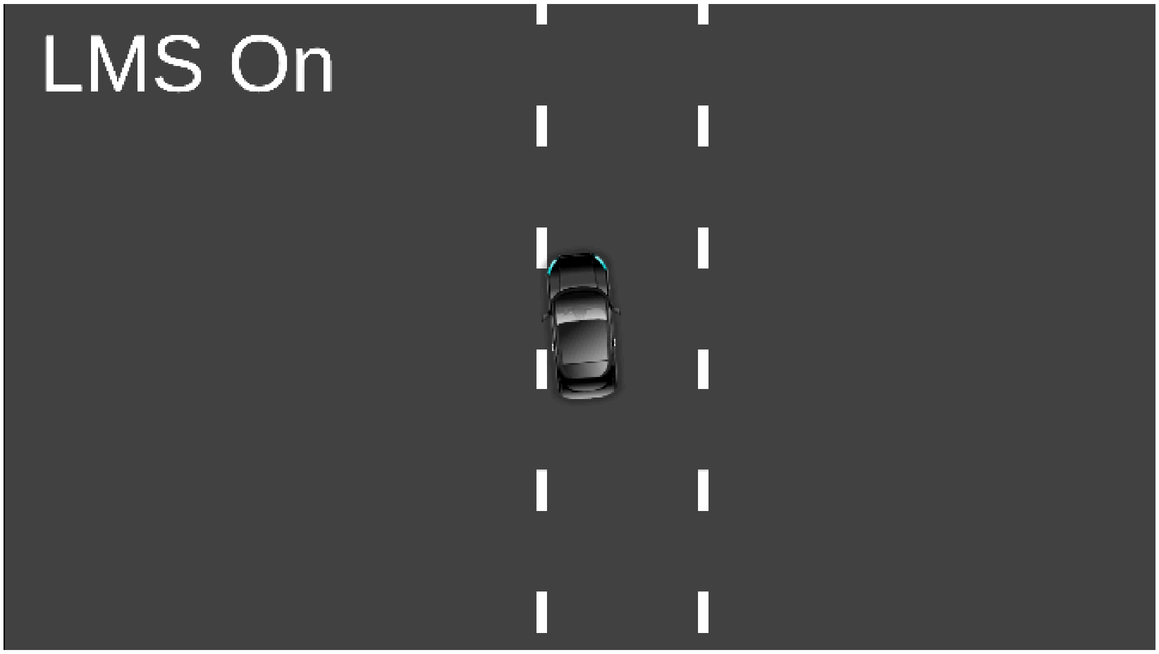
arrow keys using up and down for acceleration and left and right for steering. To ensure the prototype runs properly, use any modern up-to-date browser. Below is the link to the prototype:
https://cse.msu.edu/~baldw266/Prototype/proto.html

5.2 Sample Scenarios

The ideal scenario:



In this scenario, the car is moving forward and the lanes are being detected, so the system is active. The car is currently not making any unannounced lane departures, so the system is not applying any torque to the wheel.



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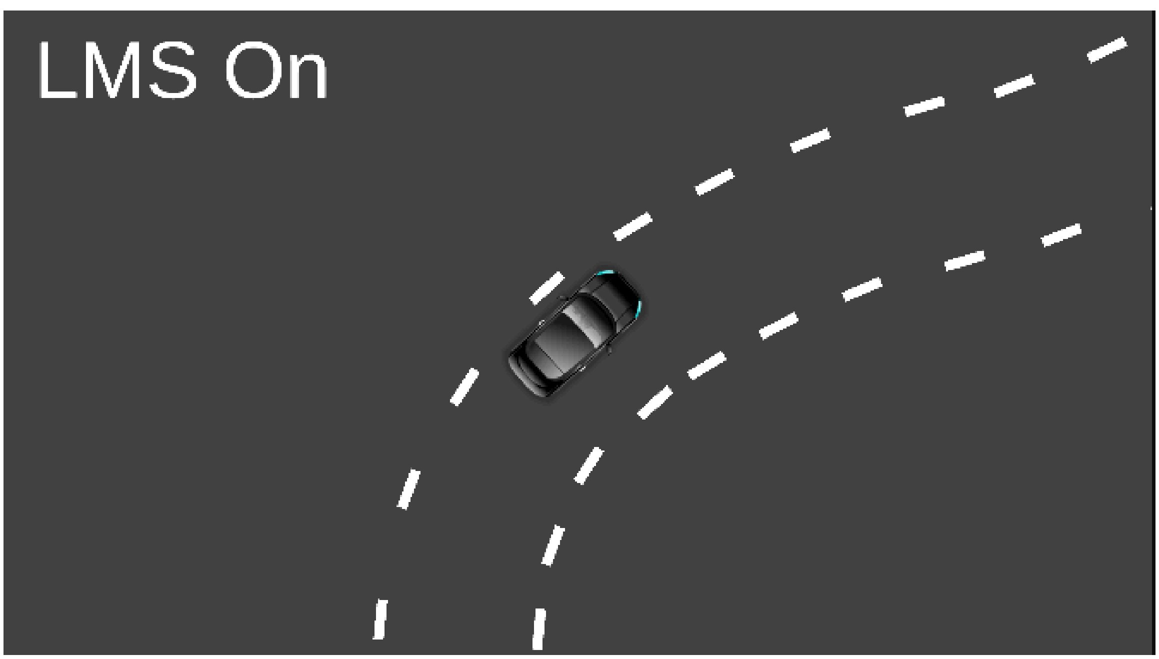
At this point, the system is on and applying torque to the wheel to keep the vehicle within the lane.

Road curvature scenario:



In this scenario, the road is not uniform and is curving. This scenario demonstrates the system continuing to work in the same fashion as the ideal scenario but under more stress.

Failure scenario:

In this scenario, the road markings are undetectable or unclear. Once the lane markings are no longer being detected, the system shuts off until lane markings are once again detected.

6 References

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Project Website Link:

https://cse.msu.edu/~baldw266/

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.