Software Requirements Specification (SRS)

Project LMS 1

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1 Introduction

In 2015, nearly 13,000 people died in single-vehicle run-off-road, head-on, and sideswipe crashes where a passenger vehicle left the lane unintentionally [1]. The prevalence of fatal accidents caused by lane departure highlights the utility of automated lane management systems which help mitigate unintentional lane departure.

This document details the requirements, functionality, elements, and uses of the Lane Management System that helps prevent automobile drivers from making unintentional driving maneuvers that endanger themselves and their surroundings.

1.1 Purpose

The purpose of the software requirements specification is to communicate to the customer the team's interpretation of the product and design which attempts to satisfy the requirements. The document contains use case diagrams which demonstrate how a user might interact with the system. The document also contains a domain model which identifies the key elements of the system and their relationships with each other. The document goes over scenarios describing the use cases provided earlier in natural language. The last universal language model used to describe the system is a state model which rigorously describes the state transitions the system undergoes under each scenario. Finally, the document describes the prototype developed to provide the customer with a tangible demonstration of the team's interpretation of the product.

1.2 Scope

LMS is an embedded system in a vehicle that provides electronic steering assistance and warnings which prevent the driver from executing unintentional driving maneuvers. To achieve this goal, the system utilizes a vehicle-mounted camera, sensor detection, electronic steering, and utilizes the sound system, infotainment screen, and steering wheel vibration to communicate with the driver. The system implements a lane departure warning subsystem which produces warnings when the driver is potentially making an unintentional maneuver and prompts them to correct their steering. The system implements a tiered warning system which produces different warnings based on their severity. The system tries to be as unobtrusive to the user as possible while also keeping them safe.

1.3 Definitions, acronyms, and abbreviations

- LMS: Lane Management System
- LDWS: Lane Departure Warning System
- LKAS: Lane Keeping Assisting System (general term for lane assistance software)
- LCS: Lane Centering System
- LKS: Lane Keeping System
- ECU: Electronic Control Unit: an embedded system in a vehicle
- ECS: Electronic Control System
- CAN: Control Area Network

1.4 Organization

The remainder of the paper is organized as follows. Section 1 introduces the customer to the scope and purpose of the product as well as the purpose and organization of the software requirements specification document.

Section 2 gives a high-level description of how the LMS works.

Section 3 contains an enumerated list of requirements divided into the categories hardware, software, and security.

Section 4 contains state, use-case, and domain models which give an abstract view of how the system executes the requirements.

Section 5 describes the prototype which gives a tangible insight into the system's operation.

Section 6 contains a list of references cited in the IEEE format.

Section 7 contains contact information for the team's instructor, Betty Cheng.

2 Overall Description

This section provides an overview of the Lane Management System (LMS-1), its role within a vehicle, and the general characteristics of its users and constraints. It also summarizes the main software functions, assumptions, and any requirements that may be deferred for future versions.

3 Product Perspective

The Lane Management System (LMS-1) is an automotive driver-assistance subsystem that helps the vehicle stay centered within its lane during normal driving. It is one part of

a larger Advanced Driver Assistance System (ADAS) environment. LMS-1 interacts with several other hardware components, including the camera, lane detection AI module, torque sensor, electronic steering system, and alert system.
The system receives real-time image data from the forward-facing camera, processes it through the lane detection AI, and uses the resulting lane position data to make steering and alert decisions. Communication between all subsystems occurs through the vehicle's CAN bus.

System Interfaces:
Camera Interface: Provides live video feed for lane detection.

Steering Interface: Receives control signals from LMS for small steering corrections.

Torque Sensor Interface: Feeds driver input data to LMS.

Alert System Interface: Receives signals to issue dashboard, haptic, or audio warnings.

CAN Bus Interface: Used for system-wide communication between LMS and vehicle modules (sub-systems).

User Interface:
The user interacts with LMS-1 primarily through the dashboard (icons and lights), audible alerts, and the physical on/off switch. No direct software interface is required.
Hardware/Software Interfaces:
Hardware includes sensors (camera, torque), electronic steering actuators, and processing units. Software includes the lane detection AI and the embedded control logic running on the LMS controller.

Communication Interfaces:
All signals between LMS and other ECSs use standardized CAN messages following automotive safety protocols.

Other/ Auxillary Constraints:
System memory and processing capacity must support real-time image and sensor analysis.

4 Product Functions

At a high level, LMS-1 performs three main functions:

- Lane Detection: The camera and AI subsystem continuously detect lane markings and calculate a confidence value.

- Lane Centering and Correction: The LMS maintains vehicle position between lane lines. When the system detects an unintentional drift (without turn signal), it applies gentle corrective torque through the steering system.

- Driver Alerting: The alert system provides tiered feedback (visual → haptic → audio) depending on how severe the situation is.

When a driver activates a turn signal, the LMS temporarily pauses its corrections to allow intentional maneuvers. If sensors fail or lane confidence drops below 95%, the system disables itself and alerts the driver until conditions improve.

Flow:
Driver → On/Off Switch → Camera → Lane Detection AI → LMS → Steering + Alert System → Driver

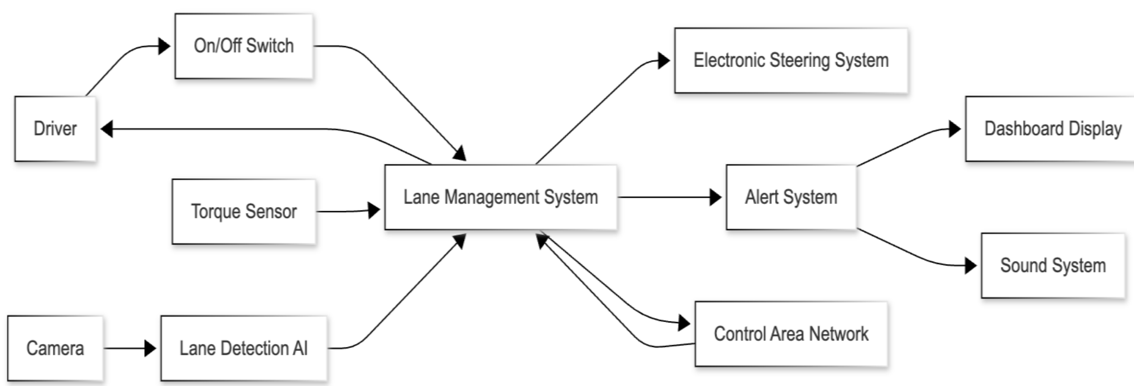

Fig1: flow chart of product functions version1

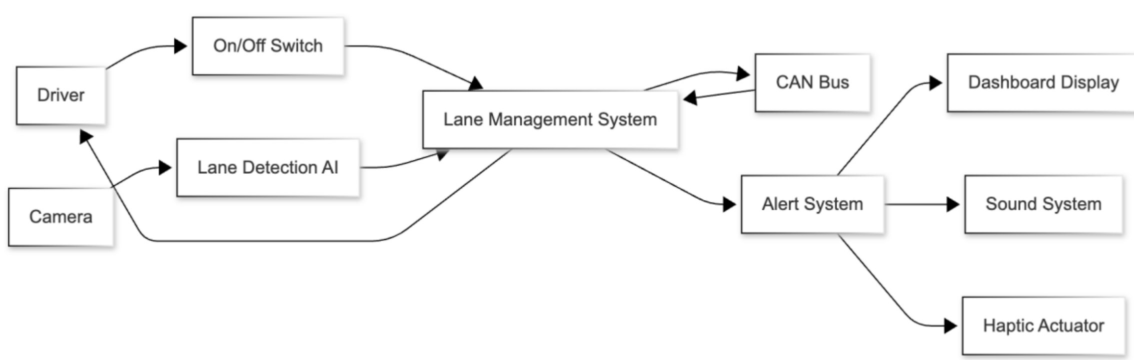

Fig2: flow chart of product functions version2

5 User Characteristics

The expected user is a licensed driver operating a vehicle equipped with LMS-1. No special training is required beyond standard driving experience. Drivers should be able to interpret dashboard symbols and auditory cues. The system assumes that users will maintain control of the vehicle at all times and may override the system by steering or braking as needed.

6 Constraints

The LMS activates only when the vehicle speed is above 35 mph and lane markings are clearly visible.

The system must deactivate if lane confidence falls below 95%, the driver exerts torque beyond the threshold, or a subsystem fault occurs.

All components must operate under typical automotive environmental conditions (temperature, vibration, lighting).

Safety-critical behavior: the driver must always retain primary control. The LMS cannot override driver input.

Performance constraint: lane detection and steering updates must occur in real-time (under 100 ms delay).

7 Assumptions and Dependencies

- Lane markings are present and visible under normal daylight or illuminated conditions.
- The camera, torque sensor, and steering systems are fully functional.
- The AI model has been trained and calibrated for standard US road conditions.
- The CAN network is reliable and free of major communication latency.
- The driver will not intentionally disable safety features while the system is active.

8 Apprpoportioning of Requirements

Some advanced capabilities are beyond the current project scope but may be considered for future releases:

- Automatic lane-change assist using predictive trajectory modeling.
- Integration with adaptive cruise control for semi-autonomous highway driving.
- Enhanced performance in poor weather or unmarked roads using map data fusion.
- Over-the-air software updates for AI model retraining and calibration.

9 Specific Requirements

10 Global Invariant Requirements

1.1. LMS activates only when turned on and deactivates when turned off.

1.2. User always has ultimate control and can override by manual steering, activating turn signal, or braking

1.3. The system should be disabled state if lane boundaries are ambiguous or undetected and resume when markings appear.

1.4. The LDWS must always work when LMS is active; if LDWS fails, LMS disables completely.

1.5. LMS must alert user on activation, interruption, or failure events.

1.6. System must disable when the user activates the turn signal or applies a torque greater than the torque applied by the system and remain disabled while the turn signal is active or the torque being applied by the driver is greater than the torque the system would apply if it was enabled.

1.7. In case of software or sensor failures, the system should notify drivers with a visual and auditory alert.

1.8. Lane-keeping assist should turn off if detection confidence goes below 0.95 and issue alert within 300 ms.

1.9. The system must not apply torque to the vehicle while the system is not in the active state.

1.10. Steering correction should not exceed 1.5 N·m.

2. Primary Requirements

2.1. Hardware

2.1.1. Camera – The system shall have a camera sensor mounted at the front center of the vehicle, positioned behind the rearview mirror at the top of the windshield. The camera shall have a range of ten feet ahead of the vehicle. The camera is used by the system to detect lane boundaries.

2.1.2. Electric Steering - Used to apply torque to the steering wheel to correct vehicle trajectory,

2.1.3. Internal Sensors – A set of sensors that periodically determine speed, steering angle, and road curvature.

2.1.4. On/Off Button – There will be a button mounted on the steering wheel which toggles the on/off status of the system.

2.1.5. Torque Sensor – There will be a torque sensor in the steering wheel to detect user steering input in case of user override of the system.

2.1.6. Haptic Actuator – There will be a haptic actuator in the steering wheel to alert the user of situations which are safety critical and require attention.

2.2. Software

2.2.1. The LMS system shall have a lane detection subsystem that identifies the lane the car is in and the distance of the vehicle from the right and left lane boundaries within tolerance of 5cm.

2.2.2. The system shall detect lane boundaries of both solid and discontinuous (dashed) lane markings regardless of curvature or color.

2.2.3. The lane detection subsystem shall compute the positions of lane boundaries with a confidence value of 0-1, indicating the percent confidence that the system has accurately identified the lane boundaries.

2.2.4. The system will issue a single warning when the system is active, and the system detects that the vehicle has entered a distance of 0.75 m (2.5 ft) of the right or left lane boundary. This warning will generate a haptic and visual alert in the steering wheel and infotainment screen, respectively. In addition, the visual LDW alert and intervention must be issued before the lane departure exceeds 0.3 m (1 ft.), and the visual LDW alert must be issued prior to, or concurrent with, the start of the intervention [2].

2.2.5. The system will issue a single warning while the system is active, and it detects that the vehicle has crossed one of the lane boundaries. This warning will be visual, haptic, and auditory, displaying an indicator on the infotainment screen until the vehicle and a vibration on the side of the steering wheel corresponding to the lane boundary that has been crossed until the vehicle returns. inside the lane boundaries or the system is disabled [2].

2.2.6. The system enters the off state when the lane management system button on the dashboard is pressed while the system is in the on state.

2.2.7. The system enters the standby state when the lane management system button on the dashboard is pressed while the system is in the on state.

2.2.8. The system will recall the previous state that the user had selected during the last session.

2.2.9. While the system is in the active state and the vehicle is between the lane boundaries, it will apply torque to the vehicle constantly to equalize the distances from the vehicle between the right and left boundaries.

2.2.10. While the system is in the active state and it is outside one of the lane boundaries, it will apply torque to the steering wheel to bring the vehicle back between the lane boundaries.

2.2.11. The system recomputes the positions of the lane boundaries whenever transitioning to the active state.

2.2.12. The dashboard should clearly show when lane assist is active, standby, or turned off.

2.2.13. The system should react fast enough to process camera input and adjust steering within 100 ms.

2.2.14. The system will implement a user interface so the driver and LMS can change parameters of system alerts for accessibility.

2.3. Security

2.3.1. When receiving a message from an over-the-air update, verify that the message is valid and not from a false or malicious source.

2.3.2. Data communicated between subsystems should be encrypted and handled appropriately to ensure that the information they contain has not been altered by an external source.

3. Secondary Requirements

3.1. Do not overwhelm the user with too many alerts.

11 Modeling Requirements

This section outlines multiple models used to describe the LMS. These models include the Use Case Diagram, Domain Model, Sequence Diagrams, and State Diagrams. To best describe system functions internally and interaction with the driver and subsystems, each diagram will follow Unified Modeling Language (UML) notation.

4.1 Use Case Diagram

The use case diagram visualizes how the system will work from the user's perspective, describing major use cases. The actors include the driver, camera, ECU, and steering system, which are shown as stick figures outside of the system boundary. Each actor represents an outside factor that interreacts with LMS. The use cases are represented as ovals, connected to their associated actors with solid lines. Dotted arrows labeled include

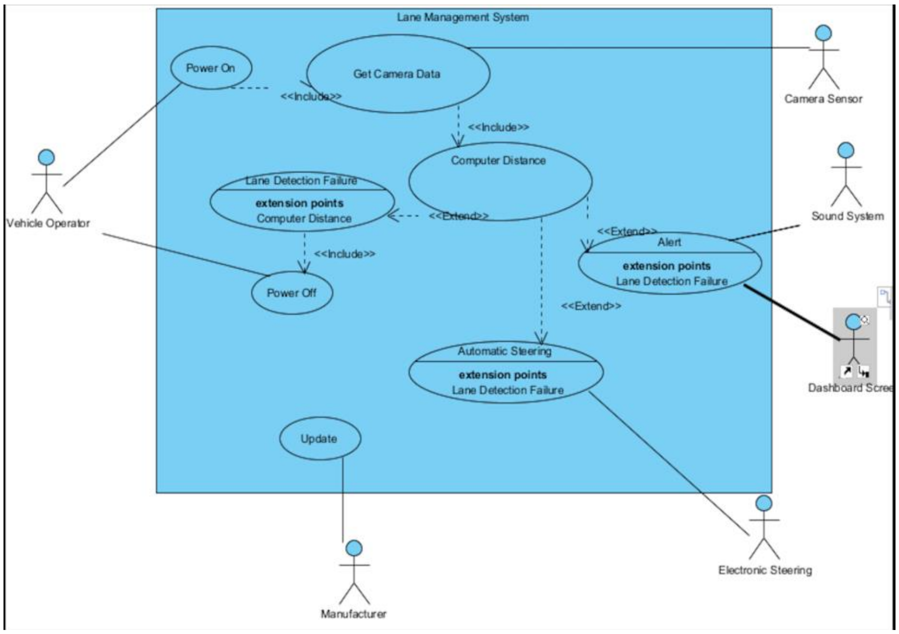

Fig3: use case diagram

b. Use case descriptions (in alphabetical order)

Use Case:	**Alert**
Actors:	**Sound System, Dashboard Screen, Vehicle Operator**
Description:	**When lane detection indicates deviation or failure, the system alerts the driver via dashboard indicators, sounds, or vibrations. The driver is warned in time to take manual corrective actions.**
Type:	**Primary (essential)**
Includes:	**None**
Extends:	**Lane Detection Failure**
Cross-refs:	**3, 4, 7, 14, 18**
Use cases:	**Automatic Steering**

Use Case:	**Automatic Steering**

Actors:	**Electronic Steering, Vehicle Operator**
Description:	**The LMS uses steering control to adjust the vehicle's position and maintain it within the detected lane. It operates only when lane data is valid and disengages when lane detection fails or the driver overrides control.**
Type:	**Primary (essential)**
Includes:	**None**
Extends:	**Lane Detection Failure**
Cross-refs:	**5, 6, 7, 15, 21, 22**
Use cases:	**Alert**

Use Case:	**Compute Distance**
Actors:	**Camera Sensor, Vehicle Operator**
Description:	**The system analyzes the images provided by the camera to calculate the vehicle's relative distance to lane boundaries. It combines sensor data with vehicle state information to determine the car's lateral position in the lane.**
Type:	**Primary (essential)**
Includes:	**Get Camera Data**
Extends:	**Lane Detection Failure**
Cross-refs:	**1, 10, 12**
Use cases:	**Automatic Steering, Alert**

Use Case:	**Get Camera Data**
Actors:	**Camera Sensor**
Description:	**The LMS retrieves live image data from the vehicle's cameras for use in lane detection and distance computation. The subsystem continuously streams camera input for analysis while the vehicle is in motion.**
Type:	**Primary (essential)**
Includes:	**None**
Extends:	**None**
Cross-refs:	**2, 8, 9, 13**
Use cases:	**Compute Distance, Lane Detection Failure**

Use Case:	**Lane Detection Failure**
Actors:	**Camera Sensor, Dashboard Screen, Vehicle Operator**
Description:	**Triggered when lane markings become unclear, missing, or unreliable. The system flags a lane detection failure, disables automatic steering if active, and notifies the driver via dashboard and audio alerts.**
Type:	**Secondary**

Includes:	**Compute Distance**
Extends:	**Alert, Automatic Steering**
Cross-refs:	**16, 17, 19**

Use Case:	**Power Off**
Actors:	**Vehicle Operator**
Description:	**The driver or system shuts down the Lane Management System. Active subsystems such as automatic steering or camera sensors are disabled in an orderly manner.**
Type:	**Secondary**
Includes:	**Lane Detection Failure**
Extends:	**None**
Cross-refs:	**16, 17, 24**
Use cases:	**None**

Use Case:	***Power On***
Actors:	***Vehicle Operator***
Description:	***The driver starts the vehicle and turns on the Lane Management System (LMS). The system initializes the sensor, cameras, and the vehicle's state estimation components to prepare for lan monitoring/detection***
Type:	***Primary (essential)***
Includes:	***Get camera data***
Extends:	***None***
Cross-refs:	***24***
Use cases:	***Lane Detection Failure Compute Distance***

Use Case:	**Update**
Actors:	**Manufacturer**
Description:	**The manufacturer provides software updates or calibration data for the Lane Management System. The system verifies the update package, installs the new firmware, and restarts if necessary.**
Type:	**Secondary**
Includes:	**None**
Extends:	**None**
Cross-refs:	**24, 25**

Use cases:	Power On

4.2 Domain Model

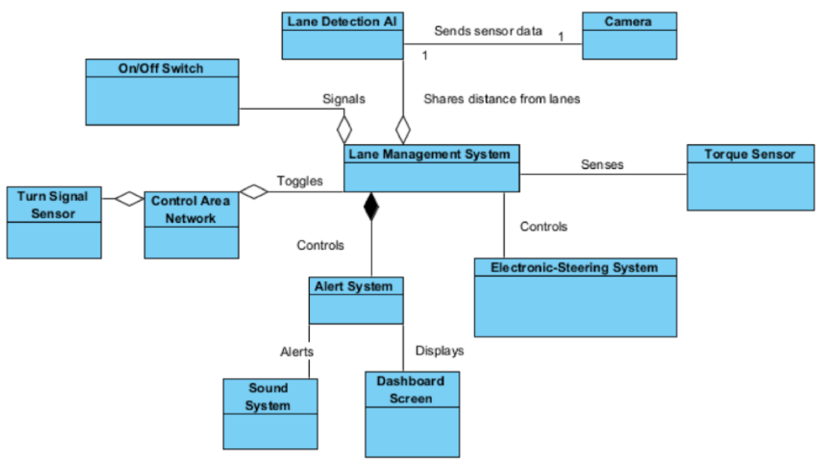

Fig4: domain model

a. Class data dictionary

Class	On/Off Switch	
	Description (responsibilities) This is what turns on and off the LMS	
	Export control (public: yes/no) yes	
		Associations:

Name	***Relationships***	Aggregations: Lane System Management
		Generalization:
	None for now	
	None for now	

Class	Lane Detection AI	
Name	***Description (responsibilities)*** The main AI that does Lane Detection	
	Export control (public: yes/no) yes	
	Relationships	Associations: Camera
		Aggregations: Lane System Management
		Generalization:
	None for now	
	None for now	

Class	Camera
	Description (responsibilities) The Camera that captures the lane.

	Export control (public: yes/no) yes	
Name	***Relationships***	Associations: Lane Detection AI
		Aggregations:
		Generalization:
	None for now	
	None for now	

Class	Lane Management System
Name	***Description (responsibilities)*** Main System
	Export control (public: yes/no) no
	Relationships — Associations: Torque Sensor, Electronic-Steering System
	Aggregations: Control Area Network
	Generalization:
	None for now
	None for now

Class	Torque Sensor

Name	***Description (responsibilities)*** Sensor that measures the steering torque	
	Export control (public: yes/no) no	
	Relationships	Associations: Lane System Management
		Aggregations:
		Generalization:
	None for now	
	None for now	
Class	Alert System	
Name	***Description (responsibilities)*** Alert system if anything fails	
	Export control (public: yes/no) no	
	Relationships	Associations: Lane Management System
		Aggregations:
		Generalization:
	List of attributes and their primitive types N/A	
	List of operations (include parameters and results) N/A	
Class	Control Area Network	

Name	**_Description (responsibilities)_** Network that controls the system		
	Export control (public: yes/no) no		
	Relationships	Associations: Turn Signal Sensor	
		Aggregations: Lane Management System	
		Generalization:	
	List of attributes and their primitive types N/A		
	List of operations (include parameters and results) N/A		
Class	Dashboard Screen		
Name	**_Description (responsibilities)_** Displays alerts and anything related to the lane management system		
	Export control (public: yes/no) yes		
	Relationships	Associations: Alert systems	
		Aggregations:	
		Generalization:	
	List of attributes and their primitive types **N/A**		
	List of operations (include parameters and results) N/A		
Class	Electronic-Steering System		

<table>
<tr><td rowspan="7">Na me</td><td colspan="2">Description (responsibilities)
System that helps the user steer properly</td></tr>
<tr><td colspan="2">Export control (public: yes/no) yes</td></tr>
<tr><td rowspan="3">Relationshi ps</td><td>Associations: Lane Management System</td></tr>
<tr><td>Aggregations:</td></tr>
<tr><td>Generalization:</td></tr>
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<tr><td colspan="2">List of operations (include parameters and results)
N/A</td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td>Cla ss</td><td colspan="2">Sound System</td></tr>
<tr><td rowspan="7">Na me</td><td colspan="2">Description (responsibilities)
System that sounds off an alert if needed</td></tr>
<tr><td colspan="2">Export control (public: yes/no) yes</td></tr>
<tr><td rowspan="3">Relationshi ps</td><td>Associations: Alert System</td></tr>
<tr><td>Aggregations:</td></tr>
<tr><td>Generalization:</td></tr>
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<tr><td>Cla ss</td><td colspan="2">Turn Signal Sensor</td></tr>
</table>

<table>
<tr><td rowspan="7">Name</td><td colspan="2">Description (responsibilities)
Sensor that signals a turn being performed</td></tr>
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4.3 Sequence Diagrams

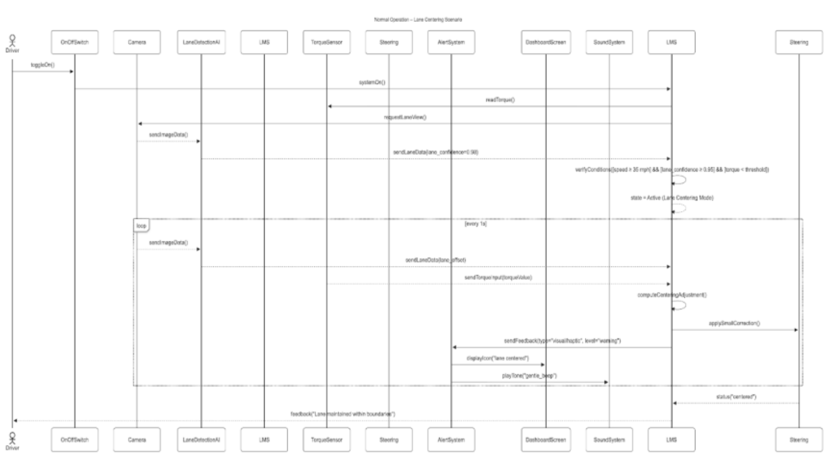


Fig5: scenario1 (normal operation) lane centering v1

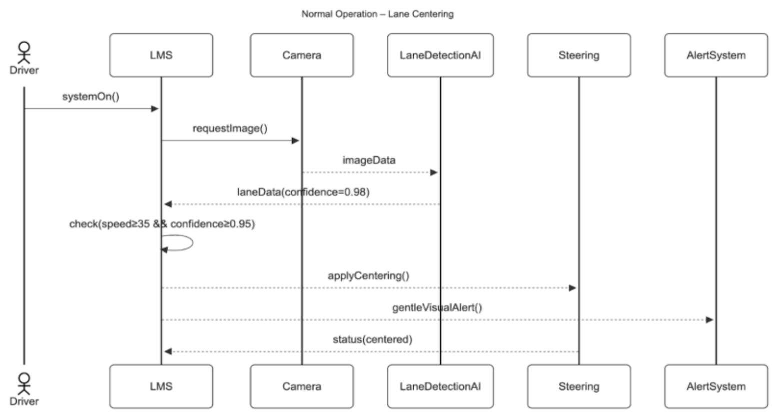


Fig6: scenario1 (normal operation) lane centering v2

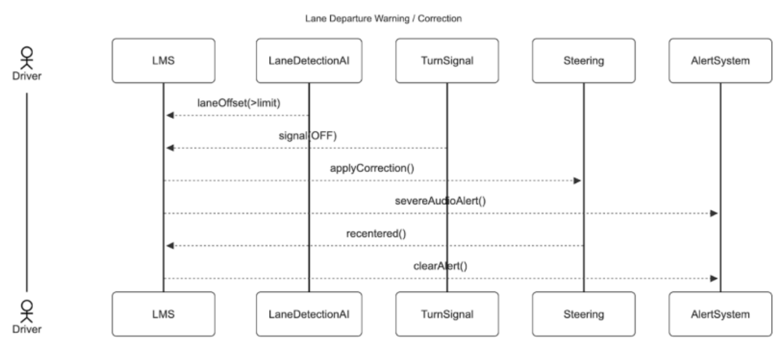


Fig7: scenario2 (exceptional case1) lane centering v1

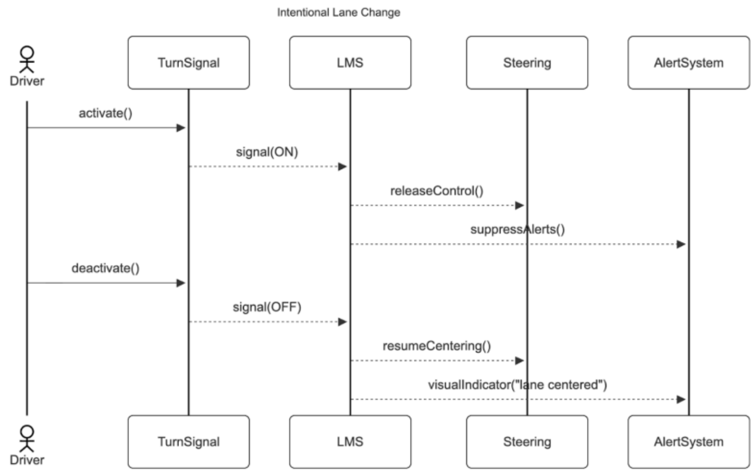


Fig8: scenario3 (exceptional case1) lane change v1

4.4 State Diagrams

Fig9: lms state diagram

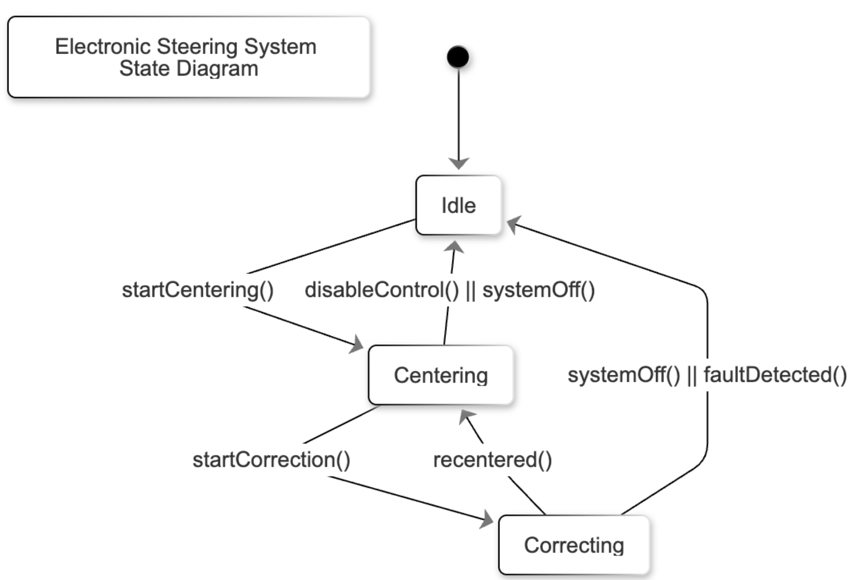


Fig10: steering state diagram

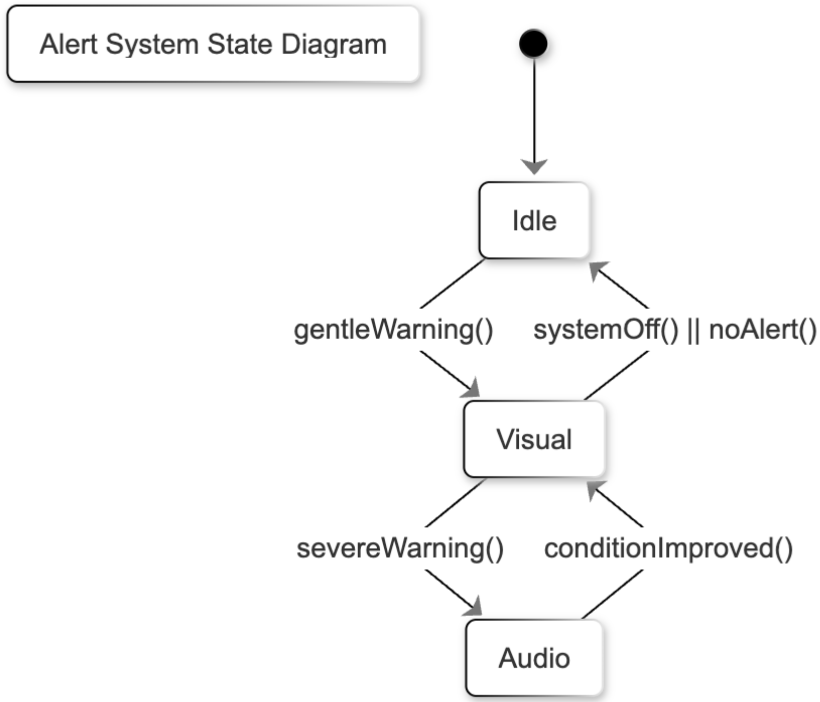


Fig11: alert system state diagram

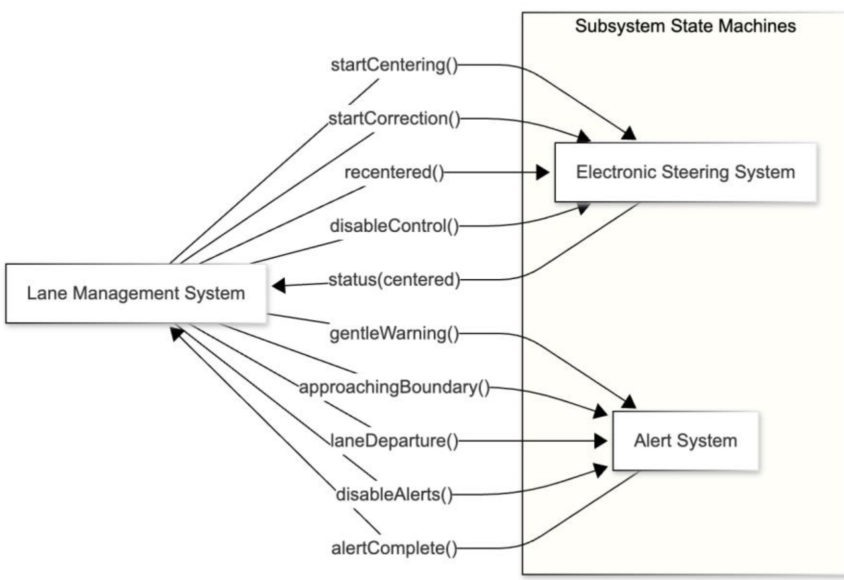


Fig12: intersecting state diagrams

12 Prototype

The purpose of this scenario is to show off the prototype of the LMS model, and how it performs in various scenarios. Below is the sample scenario of how the prototype is used. The scenario is the LMS being at its normal state with no other additions. This prototype provides the customer with an opportunity to see how the team visualizes the system's action. The prototype does not serve as a fully accurate representation of how the system works in real life.

13 How to Run Prototype

The prototype is hosted on our website https://cse435.netlify.app/. You can also access the prototype by clicking this link: https://play.unity.com/en/games/32c3fdce-0d18-4b59-9bf8-676288e5cf6e/updated-lms-1-prototype-web. When you open the prototype, you are presented with the scenario once you get click the "Normal LMS Behavior" button. The scenario plays a small animation of the vehicle acting in normal LMS behavior. There's also a "STOP" button that you can click to pause the animation at anytime.

14 Sample Scenario(s)

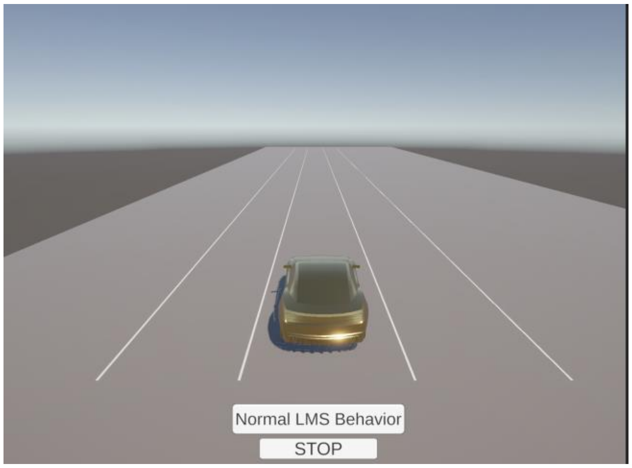
Below is the sample scenario for the LMS model. There are screen captures that illustrate the prototype at each stage of the animation along with a description.

5.2.1 Normal LMS Behavior (Perfect Condition)

The normal driving scenario describes how the LMS will operate when driving normally on a clear road. The vehicle remains in the center of the lane at the start and then veers off to the left or right randomly. This scenario shows how the system remains active and that there is no need for adjustments or warnings.

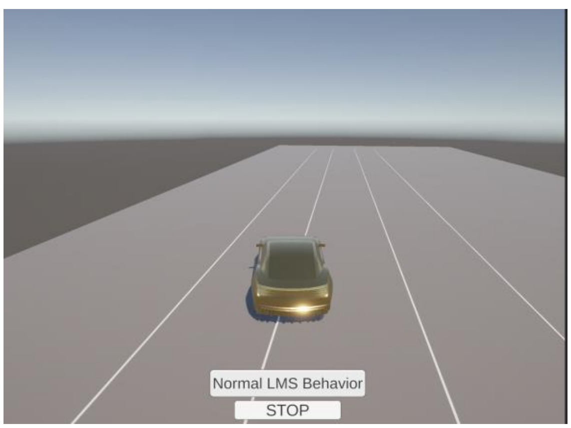
Starting State

This is the starting state of the LMS as the vehicle is in park and is ready to be driven. Once the animation is played, the car moves as normal, driving straight and in between the lanes on a clear day with no distractions.



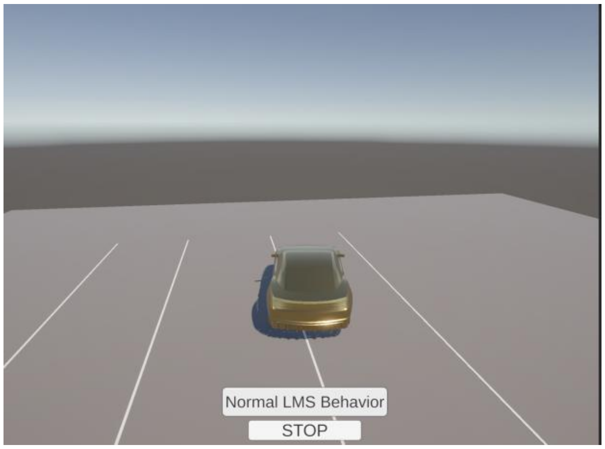
Veering off to the left

The second screen capture shows the vehicle steering off to the left at random, with nothing in its way, showing that the vehicle or user itself may have a hard time being in the lane or losing control of the car. Shortly after, the car goes back into the middle lane like it was in.



Veering off to the right

The third screen capture shows the vehicle steering off to the right at random, with nothing in its way, showing that the vehicle or user itself may have a hard time being in the lane or losing control of the car. Shortly after, the car goes back into the middle lane like it was in.



15 References

[1] J. B. Cicchino, "Effects of lane departure warning on police-reported crash rates," *Journal of Safety Research*, vol. 66, pp. 61–70, 2018, doi: https://doi.org/10.1016/j.jsr.2018.05.006.

[2] *Lane Keeping Assist and Lane Departure Warning System Confirmation Test Procedure*, National Highway Traffic Safety Administration, Washington, DC, USA, 2024.

16 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.