# Software Requirements Specification (SRS)

# Project TJA3

**Authors:** Abhinay Devapatla, Gram Boyle, Muxing Dai, Eric Gabbard, Matthew Crandall

**Customer:** William Milam

**Instructor:** Dr. Betty Cheng

## 1 Introduction

The Traffic Jam Assist (TJA) system is based on the Adaptive Cruise Control (ACC) system and expands on the ACC system to reduce the number of driver errors in traffic due to fatigue. This Software Requirements Specification (SRS) document outlines the requirements and functionality of the TJA system in depth.

### 1.1 Purpose

The purpose of an SRS document is to allow the customer to see the team's interpretation of the product and their approach to developing the desired product. This SRS document provides many diagrams that illustrate how the TJA system is intended to work. Specifically, this SRS document contains a domain model, use case diagram, sequence diagram, and a state diagram to allow the reader to become immersed in understanding the TJA system. This document is intended for stakeholders, such as the customer and developers, to understand all the components of the TJA system.

### 1.2 Scope

The TJA system allows the vehicle to perform autonomous operations on limited access highways with slow and stopped traffic. This system expands on the existing features of the ACC system with modifications for limited access highways. When the TJA system is active, it adjusts to the traffic flow by following the vehicle in front of the driver at a set distance, which the driver has three options to select from, and continuously calculated closing rate. The TJA system is intended to be a forward moving system that helps drivers navigate traffic on highways. The purpose of the TJA system is to reduce driver errors due to fatigue since the driver will no longer have to go between the accelerator and the brakes in traffic. The more often a driver does this, the more likely they are to make a mistake.

## 1.3 Definitions, acronyms, and abbreviations

- **SRS**: Software Requirements Specification, a document that describes the expected behavior of a software system.
- **TJA**: Traffic Jam Assist, the system this SRS document focuses on.
- **ACC**: Adaptive Cruise Control, the system the TJA system is based on.
- **GNSS**: Global Navigation Satellite System, a satellite system that provides positioning.
- **GPS**: Global Positioning System, communicates with GNSS to receive information about positioning.
- **Slip Condition**: The wheels are not moving at the same speed.

## 1.4 Organization

The rest of the document is organized in a way to allow optimal understanding of the TJA system. Section 2 describes and provides all the appropriate details related to the system. Section 3 enumerates all the requirements and global invariants. Section 4 illustrates multiple diagrams to effectively model the system. Section 5 includes a proof of concept to show a visual demonstration of how the system behaves.

# 2 Overall Description

The following sections give an overview of the TJA system. Section 2.1 gives more context to the TJA system and describes any constraints. Section 2.2 establishes the major goals and objectives of the software. Section 2.3 discusses what traits a user must possess to use this system. Section 2.4 mentions all the safety-critical properties and their associated constraints. Section 2.5 goes over all the assumptions and dependencies of the system. Section 2.6 explains functionality that is outside the scope of this system currently.

## 2.1 Product Perspective

The TJA system is a specialized system that works exclusively on highways with traffic. The TJA system adds additional features to the existing ACC system. The system interfaces directly into the vehicle's dashboard, allowing the driver to know when the TJA system is active. The driver can interact with the system via the "resume" and "cancel" buttons located on the steering wheel. Otherwise, the TJA system activates on limited access highways with traffic and deactivates once the highway no longer has traffic, or if the vehicle is no longer on the highway. The hardware required includes a forward-looking radar and a forward-looking camera system. The software will be added onto the existing ACC system code and only be engaged when the criteria described above are met. Additionally, the TJA system is only a forward moving system. The TJA system will not be active during operations such as lane changing or reversing.

## 2.2 Product Functions

The TJA system activates once the GPS system has determined that the vehicle is on a limited access highway with slow moving traffic. The system will proceed to use the forward-looking radar to identify a target vehicle directly in front of the driver's vehicle. Once the target vehicle has been identified, the TJA system maintains a set distance, which the driver has three options to select from, and controls the closing rate to the target vehicle. If the target vehicle starts coming to a stop, the TJA system slows down the driver's vehicle and brings it to a stop as well. When the target vehicle starts moving again, the TJA system starts moving the driver's vehicle while maintaining a set distance and controlling the closing rate. The TJA system has a forward-looking camera that enables lane following, the ability to keep the driver's vehicle in the center of its lane. The driver can completely turn off the TJA system via the "cancel" button or allow the TJA system to reactivate via the "resume" button. Once the GPS system determines there is no longer any traffic or the vehicle is no longer on a limited access highway, the TJA system shuts down and the driver will get an alert on the dashboard.

## 2.3 User Characteristics

The driver is expected to have legally obtained a driver's license and be considered fit to drive. The driver is expected to be attentively watching the road as the TJA system is active. The TJA system is a partial autonomous system, not a full autonomous system, so the driver is expected to react to behaviors outside of the scope of the system, such as the target vehicle reversing. Additionally, the driver must be able to process and comprehend dashboard messages, know how to turn the system on and off, and know how to override the system if needed. The driver must have knowledge of how the ACC system works and how to operate the additional features of the TJA system.

## 2.4 Constraints

As mentioned above, the TJA system is a forward moving system so the system is constrained to only forward moving operations. Operations such as lane changing fall outside the scope of this system and become the user's duty to perform. A safety-critical property of the system is having a functional forward-looking radar and forward-looking camera. The radar is crucial in detecting a target vehicle, distance to the target vehicle, and the speed of the target vehicle, making it a vital component of the TJA system. If the radar becomes blocked or is faulty, the TJA system disengages and gives control back to the user. Another safety-critical property is the actuators in the vehicle controlling the autonomous operations. If the actuators are faulty or not working as intended, the TJA system must disengage and give control back to the user. The system constantly checks the tires, and if a slip condition is detected, the TJA system shuts down. If the driver presses the brakes, the TJA system disengages, and control is given to the user. It becomes the driver's duty from that moment onwards to perform the necessary operations. Lastly, if the driver presses the accelerator, the TJA system disengages until the driver takes their foot off the accelerator.

## 2.5 Assumptions and Dependencies

A major underlying assumption is that the TJA system will be equipped to a car with a state-of-the-art ACC system. The TJA system is based off the ACC system; therefore, it can only be used in vehicles that already have an ACC system. Additionally, it is assumed that the ACC system comes with a forward-looking radar and a forward-looking camera. It is assumed that the TJA system will only activate on limited access highways with traffic. Lastly, it is assumed that the TJA system only engages if all the components, radars, and cameras are functioning as intended.

## 2.6 Approportioning of Requirements

The TJA system will not take weather into consideration when determining what speed to set for the driver's vehicle. For example, if the roads are covered in sleet and ice, the TJA system will not reduce the vehicle's speed by half to adjust for this. The TJA system bases its speed off the target vehicle and only adjusts its speed to the actions of the target vehicle. Additionally, lane changing is outside the scope of the TJA system. If the user decides to merge lanes, the TJA system disengages and will reengage once lane changing has been completed.

## 3 Specific Requirements

This section provides a hierarchical enumeration of the requirements of the system. These requirements include software, hardware, and safety requirements of the system.

1. The TJA system must be based on the ACC system.
   1.1. The TJA system uses a forward-looking radar to identify a target vehicle and to determine the closing rate to the target vehicle, which ideally should be zero.
      1.1.1. If the closing rate is zero, the distance between the driver's vehicle and the target vehicle is not changing, and no action is needed.
      1.1.2. If the closing rate is positive, it means that the closing distance between the driver's vehicle and target vehicle is growing, and no action is needed.
      1.1.3. If the closing rate is negative, it means that the closing distance between the driver's vehicle and target vehicle is decreasing, and the driver's vehicle needs to slow down and maintain a set distance.
         1.1.3.1. The driver must have 3 selections for the set distance: 1 car length distance (default), 2 car length distance, or 3 car length distance.
   1.2. The TJA system uses a forward-looking camera to allow lane following, the ability to keep the vehicle in the middle of the lane it is in.
   1.3. The TJA system's lane following feature resists, but not to the point of not allowing it, the driver's attempt to change lanes without signaling.
      1.3.1. The turn signal disables the lane following system to allow the driver to successfully merge into another lane.
2. The TJA system must have autonomous operations to adjust to traffic flow by following or stopping behind a target vehicle in the case of slow and stopped traffic on limited access highways.
   2.1. If the target vehicle is not moving, the TJA system stops the driver's vehicle a set distance behind the target vehicle. Specifically, the driver's vehicle must slow down and maintain a reasonable distance that allows the driver to see the rear tires of the target vehicle (default is 1 car length).
   2.2. If the target vehicle is moving, the TJA system starts the driver's vehicle and follows the target vehicle at a set distance while controlling the closing rate. Specifically, the vehicle must follow at a set distance (default is 1 car length) and continuously recalculate the closing rate.
3. The TJA system will only be activated when the GPS tracking device indicates that the vehicle is on a limited access highway and that there is traffic on the highway.
   3.1. The GPS tracking device must be able to communicate with the Global Navigation Satellite System (GNSS) network [1, pp. 2] to retrieve information about the traffic on the road and the vehicle's current position, which is checked against the vehicle's internal database of limited access highways.
   3.2. The TJA system ensures end-to-end encryption when the GPS communicates with the GNSS and when the GPS communicates with the internal database.
4. The TJA system alerts the driver of warnings when the closing distance is negative, the vehicle speed is too high, or the vehicle is not lane following.

4.1. The TJA system displays warnings on the dashboard.
4.2. The TJA system has an auditory warning system consisting of beeps.

5. The TJA system is purely a forward moving system.
   5.1. The TJA system will not be active during lane changing.
      5.1.1. After lane changing, the TJA system resumes at the previous set speed if there are no new target vehicles.
      5.1.2. After lane changing, the TJA system recalculates the set speed and closing distance after identifying a new target vehicle.
   5.2. If the target vehicle starts reversing, it falls outside the scope of the TJA system and becomes the driver's duty to make the appropriate action. In other words, the TJA system disengages if the target vehicle shifts into reverse.
   5.3. If there are inclement weather conditions, it falls outside the scope of the TJA system and becomes the driver's duty to make the appropriate action.
6. The TJA system ensures that the driver is attentively paying attention to the road.
   6.1. Tactile feedback sends vibrations to the steering wheel to determine if the driver's hands are on the wheel.
   6.2. A driver-facing infrared camera determines if the driver is looking at the road.
7. If the TJA system needs to disengage, it informs the driver on the dashboard and deactivates.
   7.1. The TJA system disengages if the radar sensor is faulty or blocked.
   7.2. The TJA system disengages if the system detects a slip condition.
   7.3. The TJA system disengages if the forward-looking camera is faulty.
   7.4. The TJA system disengages if the driver is not paying attention to the road.
8. The driver must easily be able to take control of the vehicle from the TJA system.
   8.1. If the driver taps the brakes, the TJA system disengages.
   8.2. If the driver accelerates, the TJA system allows them to, but after they take their foot off the accelerator, the system returns to the set speed.
9. The buttons "resume" and "cancel" will be installed to the steering wheel to resume/cancel the TJA system.
   9.1. The resume button brings the vehicle back to its previous set speed.
   9.2.The cancel button turns the system off, including the ability to resume.

**<u>Global Invariants of the TJA system</u>**

1. The vehicle shall not exceed 10 mph if a target vehicle is detected within 15 feet.
2. The vehicle shall maintain a distance of at least 1 car length to the target vehicle.
3. The vehicle shall never surpass 80 mph when the TJA system is active.
4. The driver shall be able to select a set distance.
5. The TJA system is only a forward moving system.

# 4 Modeling Requirements

This section contains models that help to better illustrate and describe the TJA system. This section included a use-case diagram, domain model, sequences diagrams, and state diagrams.

## 4.1 Use Case Diagram

The use case diagram in **Figure 1** below illustrates all the use cases of the TJA system. The system boundary is represented by the rectangle, the actors are represented by the stick figures, the use cases are represented by circles, and associations between actors and use cases are represented by lines. Some use cases have a unique relationship indicated by “<include>” or “<extend>”. When use cases have a piece of behavior that is similar across them, the use cases include this common use case. When use cases are similar to other use cases, but have additional functionality, the use cases extend for the similar use case. The system boundary for this use case diagram is the TJA system.

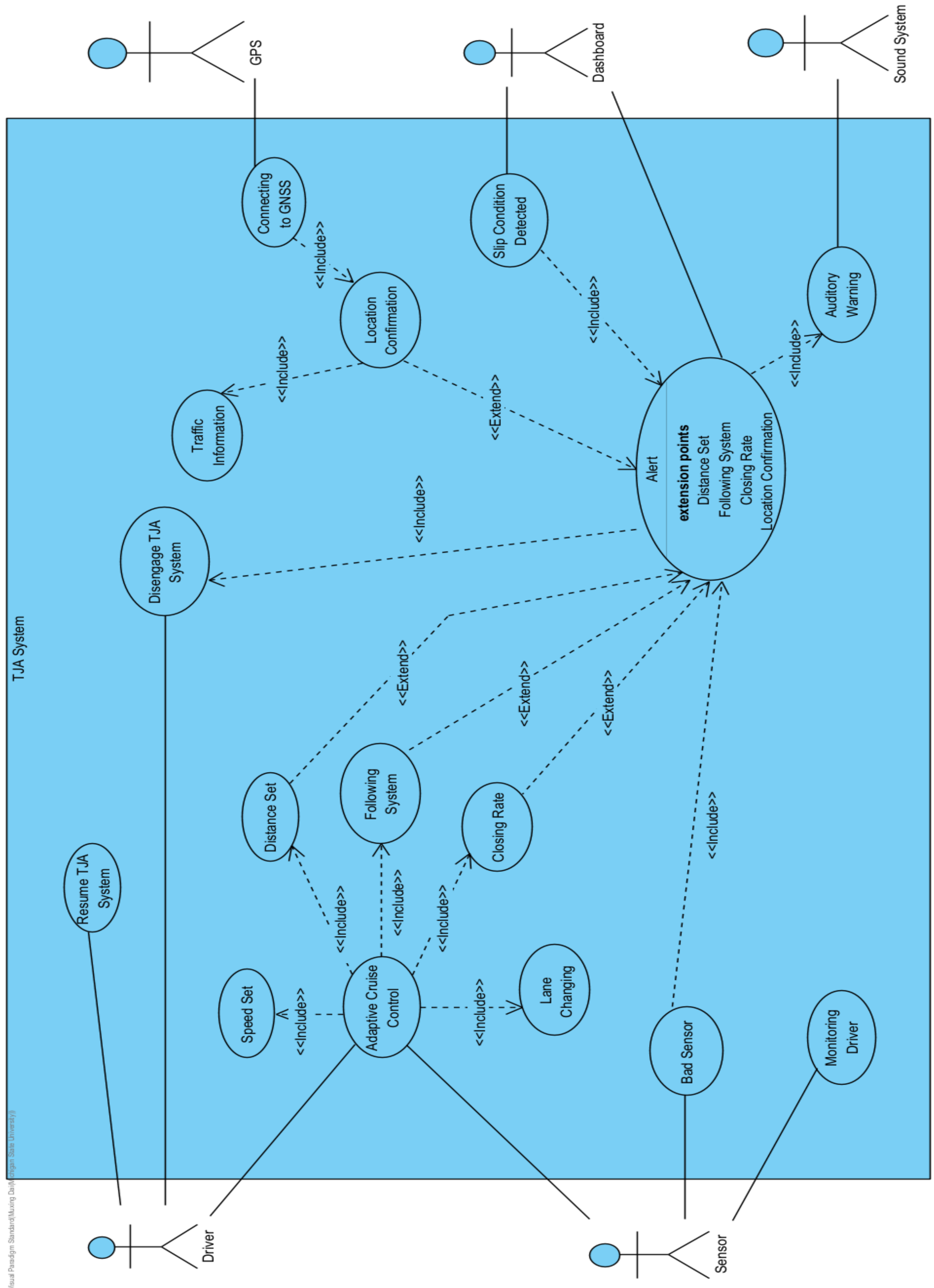


**Figure 1**: Use Case Diagram for TJA system

The tables provided below go further into detail about the use cases.

| | |
|---|---|
| Use Case: | Resume TJA System |
| Actors: | Driver |
| Description: | The TJA system cannot restore itself, and the driver can restore it manually through the buttons on the steering wheel. |
| Type: | Primary and essential |
| Include: | None |
| Extend: | None |
| Cross-refs: | 5.3, 9, 9.1 |
| Use cases: | None |

**Table 1**: Resume TJA System

| | |
|---|---|
| Use Case: | Disengage TJA System |
| Actors: | Driver and System |
| Description: | TJA will issue a warning and then self-disable in many situations, such as invalid highway, bad sensor, slip condition detected, etc. Drivers can also disable TJA by decelerating or manual button. |
| Type: | Primary and essential |
| Include: | None |
| Extend: | None |
| Cross-refs: | 5, 8, 8.1, 9.2 |
| Use cases: | None |

**Table 2**: Disengage TJA System

| | |
|---|---|
| Use Case: | Adaptive Cruise Control |
| Actors: | Driver, Sensor, System |
| Description: | TJA is a higher-level system based on ACC, with completed ACC functions. |
| Type: | Primary and essential |
| Include: | Speed Set, Distance Set, Following System, Closing Rate, Lane Changing |
| Extend: | None |
| Cross-refs: | 1 |
| Use cases: | Speed Set, Distance Set, Following System, Closing Rate, Lane Changing |

**Table 3**: Adaptive Cruise Control

| | |
|---|---|
| Use Case: | Speed Set |
| Actors: | Driver, Sensor, System |
| Description: | Driver can set a default speed for TJA, which should be less than 80 mph. |
| Type: | Primary and essential |
| Include: | None |
| Extend: | None |
| Cross-refs: | 8.2 |
| Use cases: | None |

**Table 4:** Speed Set

| | |
|---|---|
| Use Case: | Distance Set |
| Actors: | Driver, Sensor, System |
| Description: | Driver can set the distance between vehicle and front car. There are 3 options, one car length(default), two car length, three car length. When distance is too close there will be an alert. |
| Type: | Primary and essential |
| Include: | None |
| Extend: | Alert |
| Cross-refs: | 1.1.3.1 |
| Use cases: | Alert |

**Table 5**: Distance Set

| | |
|---|---|
| Use Case: | Following System |
| Actors: | Driver, Sensor, System |
| Description: | The TJA system must have autonomous operations to adjust to traffic flow by following or stopping behind a target vehicle in the case of slow and stopped traffic on limited access highways. If the target vehicle starts reversing, it falls outside the scope of the TJA system and becomes the driver's duty to make the appropriate action. |
| Type: | Primary and essential |
| Include: | None |
| Extend: | Alert |
| Cross-refs: | 1.2, 1.3, 2, 2.1, 2.2, 5.2 |
| Use cases: | Alert |

**Table 6**: Following System

| | |
|---|---|
| Use Case: | Closing Rate |
| Actors: | Driver, Sensor, System |
| Description: | The TJA system uses a forward-looking radar to identify a target vehicle and to determine the closing rate to the target vehicle, which ideally should be zero. If the closing rate is negative, it means that the closing distance between the driver's vehicle and target vehicle is decreasing, and the driver's vehicle needs to slow down and maintain a set distance. |
| Type: | Primary and essential |
| Include: | None |
| Extend: | Alert |
| Cross-refs: | 1.1, 1.1.1, 1.1.2, 1.1.3, 4 |
| Use cases: | Alert |

**Table 7**: Closing Rate

| | |
|---|---|
| Use Case: | Lane Changing |
| Actors: | Driver, Sensor, System |
| Description: | The TJA system will not be active during lane changing. If the user decides to merge lanes, the TJA system disengages and will reengage once lane changing has been completed. |
| Type: | Primary and essential |
| Include: | None |
| Extend: | None |
| Cross-refs: | 1.3.1, 5.1, 5.1.1, 5.1.2 |
| Use cases: | None |

**Table 8**: Lane Changing

| | |
|---|---|
| Use Case: | Bad Sensor |
| Actors: | Sensor |
| Description: | The TJA system disengages if the radar sensor is faulty or blocked. There will be an alert to warn driver. |
| Type: | Primary and essential |
| Include: | Alert |
| Extend: | None |
| Cross-refs: | 7.1, 7.3 |
| Use cases: | Alert |

**Table 9**: Bad Sensor

| | |
|---|---|
| Use Case: | Monitoring Driver |
| Actors: | Sensor |
| Description: | A driver-facing infrared camera determines if the driver is looking at the road. |
| Type: | Primary and essential |
| Include: | None |
| Extend: | None |
| Cross-refs: | 6, 6.1, 6.2, 7.4 |
| Use cases: | None |

**Table 10**: Monitoring Driver

| | |
|---|---|
| Use Case: | Alert |
| Actors: | Dashboard, Sound System, GPS, Sensor |
| Description: | The alarm is the precursor to disabling TJA. There are many possible reasons for the alarm, and most of them are the same as the reason for disengaging TJA. |
| Type: | Primary and essential |
| Include: | Auditory Warning, Disengage TJA System |
| Extend: | None |
| Cross-refs: | 4.1, 7 |
| Use cases: | Auditory Warning, Disengage TJA System |

**Table 11**: Alert

| | |
|---|---|
| Use Case: | Auditory Warning |
| Actors: | Sound System |
| Description: | The car's own sound system can make a beep sound to remind the driver when alert. |
| Type: | Primary |
| Include: | None |
| Extend: | None |
| Cross-refs: | 4.2 |
| Use cases: | None |

**Table 12**: Auditory Warning

| | |
|---|---|
| Use Case: | Slip Condition Detected |
| Actors: | Dashboard |
| Description: | When slip occurs due to conditions such as severe weather, the dashboard displays and issues an alert while disabling TJA. |
| Type: | Primary and essential |
| Include: | Alert |
| Extend: | None |
| Cross-refs: | 7.2 |
| Use cases: | Alert |

**Table 13**: Slip Condition Detected

| | |
|---|---|
| Use Case: | Connecting to GNSS |
| Actors: | GPS |
| Description: | The TJA system connects to GNSS via GPS to get the latest road and traffic conditions. |
| Type: | Primary and essential |
| Include: | Location Confirmation |
| Extend: | None |
| Cross-refs: | 3.1, 3.2 |
| Use cases: | Location Confirmation |

**Table 14**: Connecting to GNSS

| | |
|---|---|
| Use Case: | Location Confirmation |
| Actors: | GPS |
| Description: | By connecting to GPS, you can easily position yourself. If the highway you are on is not available, TJA will sound an alert and disengage itself. |
| Type: | Primary and essential |
| Include: | Traffic Information |
| Extend: | Alert |
| Cross-refs: | 3 |
| Use cases: | Traffic Information, Alert |

**Table 15**: Location Confirmation

| | |
|---|---|
| Use Case: | Traffic Information |
| Actors: | GPS |
| Description: | If the highway you are on is available, TJA will provide you with traffic information through GPS to better assist driving. |
| Type: | Primary |
| Include: | None |
| Extend: | None |
| Cross-refs: | 3.1, 3.2 |
| Use cases: | None |

**Table 16**: Traffic Information

## 4.2 Domain Model

The domain model, in **Figure 2** below, illustrates all the relationships of the TJA system. The domain model was developed using UML class diagram notation. The classes are represented by blue boxes. The top rectangle of the class is the name of the class, and the bottom rectangle contains attributes and functions. There are many types of relationships between the classes. The line between classes is an association. If there is an empty diamond on one side of the association, it is composition. If there is a filled diamond on one side of the association, it is aggregation. Finally, the association has multiple on each side, indicating a quantifiable relationship.

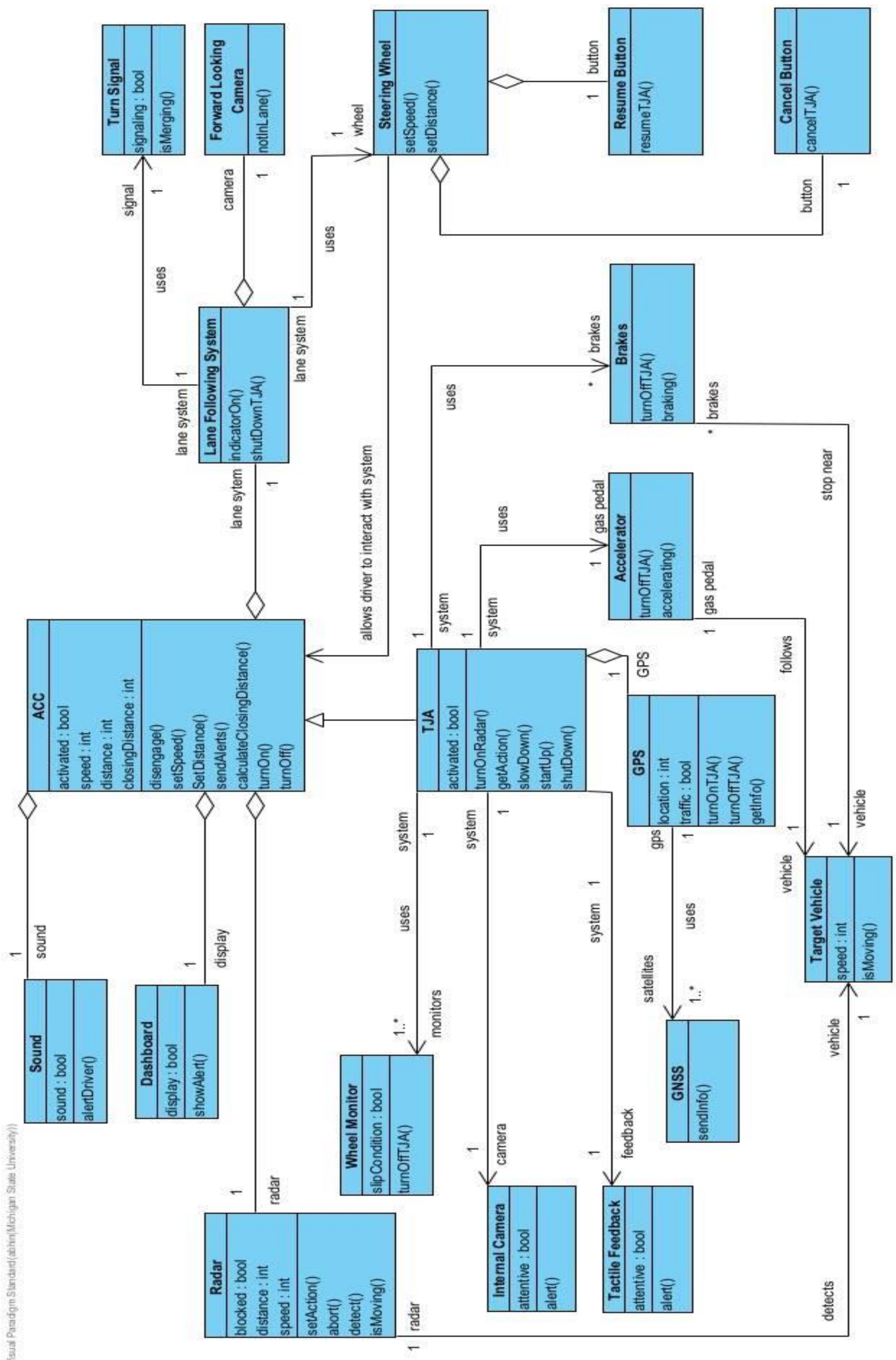


**Figure 2**: Domain Model for the TJA system

The data dictionary provided below goes further into detail about the domain model.

| **Element Name** | **Description** |
|---|---|
| Brakes | Pressed by the operator to take control of the system. Brakes turn off the TJA system. TJA systems uses the brakes when closing speed is negative. |
| Attributes | None |
| Operations | turnOffTJA()<br>braking() |
| Relationships | None |
| | TJA. TJA uses the brakes to stop/slow the vehicle if the closing speed is negative. The Brake pedal also disengages the TJA if the driver uses it. |
| UML Extensions | None |

**Table 17**: Brakes

| **Element Name** | **Description** |
|---|---|
| Accelerator | Pressed by the operator if they want to accelerate. Stops the TJA system momentarily but it resumes once accelerator is released. TJA system uses the accelerator if target car is further away than the set distance. |
| Attributes | None |
| Operations | turnOffTJA()<br>accelerating() |
| Relationships | None |
| | TJA. TJA uses the accelerator to speed up the vehicle if the target vehicle is more than the set distance away. Also, the accelerator pedal is pushed by the operate to disengage and resume the TJA. |
| UML Extensions | None |

**Table 18**: Accelerator

| **Element Name** | **Description** |
|---|---|
| ACC | This system that the TJA is derived from. The user sets a speed and distance using the dashboard and steering. Then using radars, the ACC will keep the car within that set distance from the target car. |
| Attributes | activated: bool<br>speed: int<br>distance: int<br>closingDistance: int |
| Operations | disengage()<br>setSpeed()<br>setDistance()<br>sendAlerts()<br>calculateClosingDistance()<br>turnOn()<br>turnoff() |
| Relationships | Dashboard. Aggregation. Uses the dashboard to send alerts to the driver. |
| | Rader. Aggregation. Radar lets the ACC know whether to break or accelerate based off target vehicle. |
| | Lane Following System. Aggregation. The ACC uses the Lane Following system to stay within the lanes. |
| | Brakes Usage. Uses the brakes to maintain the set following distance |
| | Accelerator. Usage. Uses the accelerator to keep set following distance. |
| | None |
| UML Extensions | None |

**Table 19**: ACC

| **Element Name** | **Description** |
|---|---|
| Dashboard | The dashboard is the screen located behind the steering wheel and it is used to deliver alerts and messages to the driver. |
| Attributes | display: bool |
| Operations | showAlert() |
| Relationships | ACC. Aggregation. The ACC sends alerts to the dashboard to be displayed to the driver. |
| UML Extensions | None |

**Table 20**: Dashboard

| Element Name | Description |
|---|---|
| Sound | The sound is used to alert the driver. This sound is activated when the TJA system is disengaged. |
| Attributes | sound: bool |
| Operations | alertDriver() |
| Relationships | ACC. Aggregation. The ACC system alerts the driver with sounds when something goes wrong. For example, if a camera is covered, the driver will be alerted with a sound. |
| UML Extensions | None |

**Table 21**: Sound

| Element Name | Description |
|---|---|
| Radar | The radar is used to detect vehicles and objects in front of the driver's vehicle. If the radar is blocked, the ACC system should turn off |
| Attributes | blocked: bool<br>speed: int<br>distance: int |
| Operations | setAction()<br>abort()<br>detect()<br>isMoving() |
| Relationships | ACC. Aggregation. ACC uses the radar to spot objects up ahead. If a radar is blocked, the ACC should turn off. |
| | Target Vehicle. Usage. Uses the target vehicle to calculate the target's location. |
| UML Extensions | None |

**Table 22**: Radar

| Element Name | Description |
|---|---|
| Wheel Monitor | Used to check the wheels for slippage. The TJA system will turn off if slippage is detected. |
| Attributes | slipCondition: bool |
| Operations | turnoffTJA() |
| Relationships | TJA. Usage. Alerts the TJA if a slip condition is present and turns the TJA off. |
| UML Extensions | None |

**Table 23**: Wheel Monitor

| Element Name | Description |
|---|---|
| Internal Camera | Checks the driver to see where his eyes are looking. Determines if the driver is active and paying attention to the road. If the driver is not, it should send a notification to the system. |
| Attributes | attentive: bool |
| Operations | alert() |
| Relationships | TJA. Usage. Alerts the TJA if the driver is not actively looking at the road. |
| UML Extensions | None |

**Table 24**: Internal Camera

| Element Name | Description |
|---|---|
| Tactile Feedback | Determines if the driver is active and attentive based off the pressure on the steering wheel. The TJA should be alerted if the driver does not have his hands on the wheel for an extended period. |
| Attributes | attentive: bool |
| Operations | alert() |
| Relationships | TJA. Usage. Alerts the TJA if the driver is not actively using the steering wheel. |
| UML Extensions | None |

**Table 25**: Tactile Feedback

| Element Name | Description |
|---|---|
| Lane Following System | The lane following system uses cameras and the steering wheel to keep the car in the lane. If the cameras notice that the car is going outside marked lanes and a turn signal is not being used, the wheel will resist it to an extent. |
| Attributes | None |
| Operations | indicatorOn()<br>shutDownTJA() |
| Relationships | Steering Wheel. Usage. Turns the steering wheel to stay in lane. |
| | Turn Signal. Usage. Lane following system only uses the wheel if the turn signal is not active. |
| | Camera. Aggregation. Uses the camera to check if the vehicle is within the lanes. |
| UML Extensions | None |

**Table 26**: Lane Following System

| **Element Name** | **Description** |
|---|---|
| Forward-Looking Camera | This is the camera that is used to check the lane marking position relative to the car. |
| Attributes | None |
| Operations | notInLane() |
| Relationships | Lane Following System. The camera notifies the Lane Following System if the car strays from the lane markers. |
| UML Extensions | None |

**Table 27**: Camera

| **Element Name** | **Description** |
|---|---|
| Turn Signal | The driver uses the turn signal to warn other drivers that they are turning or changing lanes. The turn signal is also used to alert the lane following system that the car is turning intentionally, and it should not override the steering wheel. |
| Attributes | signaling: bool |
| Operations | isMerging() |
| Relationships | Lane Following System. Usage. The turn signal is used to alert the lane following system that the car is turning intentionally, and it should not override the steering wheel. |
| UML Extensions | None |

**Table 28**: Turn Signal

| Element Name | Description |
|---|---|
| Steering Wheel | Used by the driver to direct the car. The lane following system can also override the steering wheel if the car is leaving the lane. |
| Attributes | None |
| Operations | setSpeed()<br>setDistance() |
| Relationships | Lane Following System. Usage. If it is determined by the Lane Following System that the vehicle is unintentionally leaving its lane, the lane following system will override the steering wheel to reposition the car. |
| | ACC. Usage. Allows the user to interact with the ACC. The driver sets the speed and following distance using the steering wheel |
| | Resume Button. Aggregation. The resume button is used to resume the ACC through the steering wheel. |
| | Cancel Button. Aggregation. The cancel button is used to cancel the ACC through the steering wheel. |
| UML Extensions | None |

**Table 29**: Steering Wheel

| Element Name | Description |
|---|---|
| Resume Button | Used by the driver to reactivate the ACC/TJA. Located on the steering wheel. |
| Attributes | None |
| Operations | resumeTJA() |
| Relationships | Steering Wheel. Aggregation. The resume button is used to resume the ACC through the steering wheel. |
| UML Extensions | |
| **Element Name** | **Description** |
| Cancel Button | Used by the driver to cancel the ACC/TJA. Located on the steering wheel. |
| Attributes | None |
| Operations | cancelTJA() |
| Relationships | Aggregation. The resume button is used to cancel the ACC through the steering wheel. |
| UML Extensions | None |

**Table 30**: Resume and Cancel Button

| Element Name | Description |
|---|---|
| TJA | The primary system that deviated from the ACC. Intended to help drivers in stop and go traffic. Should automatically activate when on a highway with traffic. |
| Attributes | activated: bool |
| Operations | turnOnRadar()<br>getAction()<br>slowDown()<br>startUp()<br>shutDown() |
| Relationships | GPS. Aggregation. The GPS will automatically turn on the TJA system if it determined that the vehicle is on a highway with traffic. |
| | Wheel Monitors. Usage. The wheel monitors will automatically turn off the TJA if a slip condition is identified. |
| | Brakes Usage. The system will override the brakes if it is determined that there is a negative closing distance. Brakes also turn system off if the user activates them. |
| | Accelerator. Usage. The system will override the accelerator if it is determined that there is a positive closing distance. Accelerators also temporarily turn the system off if the user activates them. |
| UML Extensions | None |

**Table 31**: TJA

| Element Name | Description |
|---|---|
| GPS | The GPS is used to find the vehicle's position as well as determine if the vehicle is on a highway with traffic. If the vehicle is on a highway with traffic, the TJA will be activated. |
| Attributes | location: int<br>traffic: bool |
| Operations | turnOnTJA()<br>turnOffTJA()<br>getInfo() |
| Relationships | TJA. Aggregation. The GPS determines if the vehicle is on a limited access highway and will turn on TJA if that is the case. It will also turn off the TJA when the car exits a traffic situation. |
| | GNSS. Communication. Communicates with the GNSS to determine the vehicle's location and if the vehicle is on a limited access highway. |
| UML Extensions | |
| **Element Name** | **Description** |
| GNSS | The Global Navigation Satellite System. Sends vehicle location and traffic information to the GPS system. |
| Attributes | None |
| Operations | sendInfo() |
| Relationships | GPS. Communication. Sends vehicle location and traffic information to the GPS system. |
| UML Extensions | None |

**Table 32**: GPS and GNSS

| Element Name | Description |
|---|---|
| Target Vehicle | The target vehicle determines the actions of the TJA and the user's car. |
| Attributes | speed: int |
| Operations | isMoving() |
| Relationships | Radar. The radar locates the target vehicle and sends this information to the TJA |
| | Brakes. The brakes are activated based off the speed of the target vehicle. |
| | Accelerator. The accelerator is activated based off the speed and location of the target vehicle. |
| UML Extensions | None |

**Table 33**: Target Vehicle

## 4.3 Sequence Diagram

In this section, six sequence diagrams are illustrated to further elaborate on how specific scenarios are handled in the TJA system. The lifeline is indicated by the blue box with a line going out of it. The messages between objects are indicated by the arrow between the dotted lines. The messages are ordered in the order they occur.

**Figure 3**, below, shows the scenario of activating the TJA system. The GPS system lets the TJA system know its current location and traffic at that location, dictating when the TJA system should activate. After activation, the TJA system turns on the forward-looking radar and determines the target vehicle in front of the driver's vehicle.

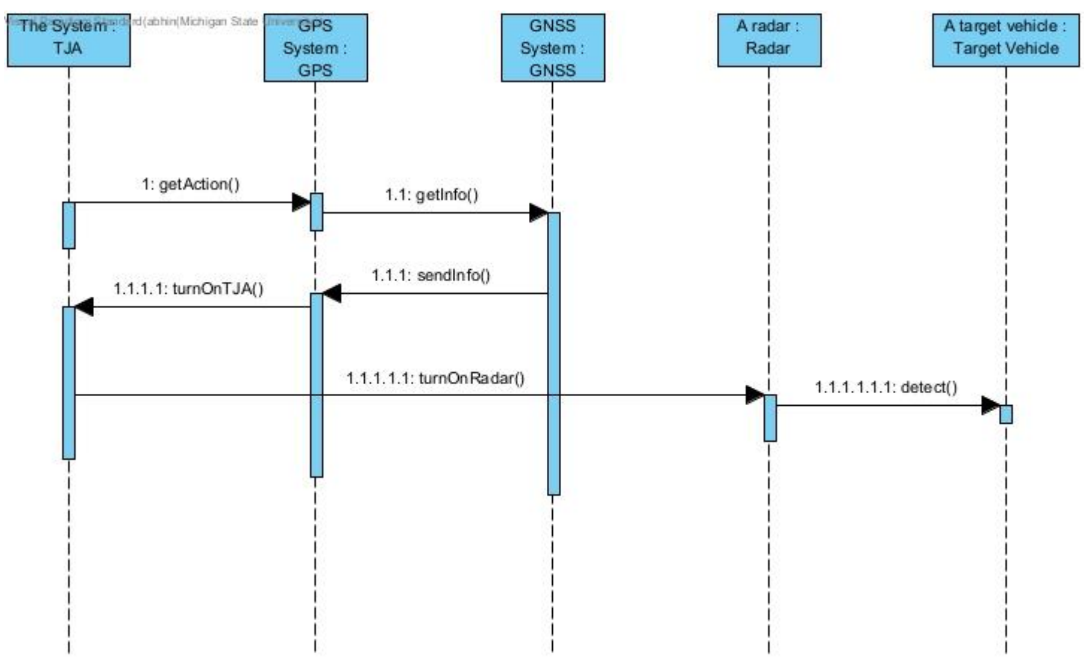


**Figure 3**: Scenario 1

**Figure 4**, below, shows the scenario of the TJA system slowing down the driver's vehicle. The radar determines if the target vehicle is moving or not. After the radar lets the TJA system know that the target vehicle is not moving, the TJA system engages the brakes to slow down and come to a stop.

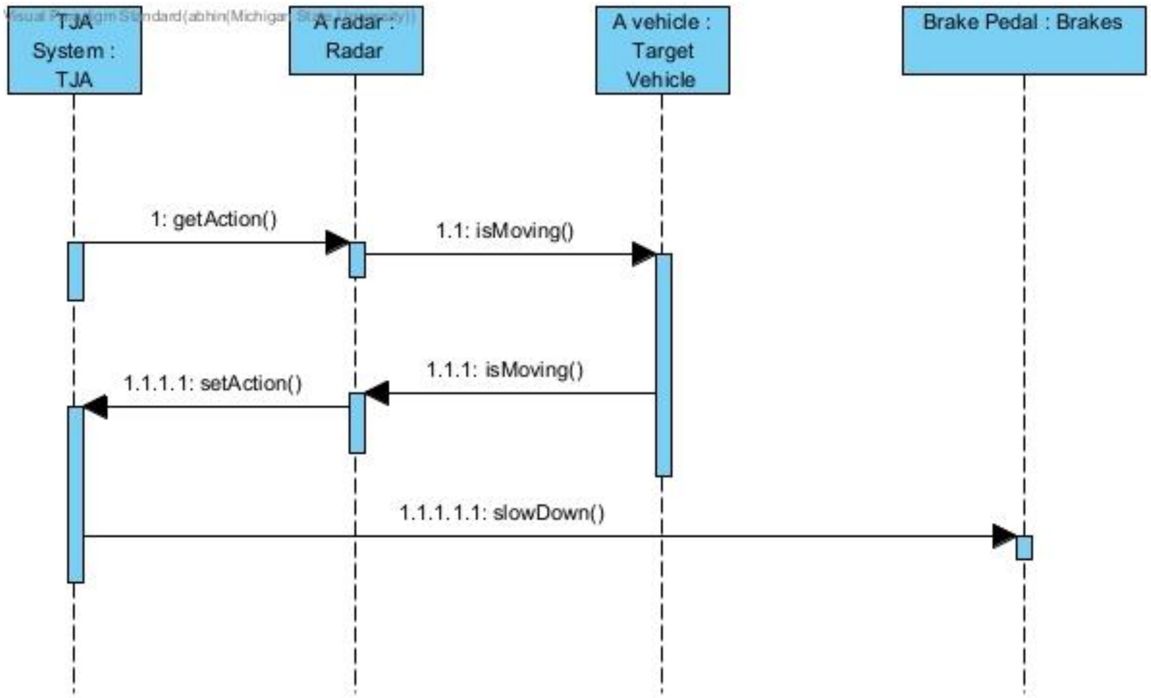


**Figure 4**: Scenario 2

**Figure 5**, below, shows the scenario of the TJA system starting up the driver's vehicle. The radar determines if the target vehicle is moving or not. After the radar lets the TJA system know that the target vehicle is moving, the TJA system engages the accelerator to speed up and maintain a set distance to the target vehicle.

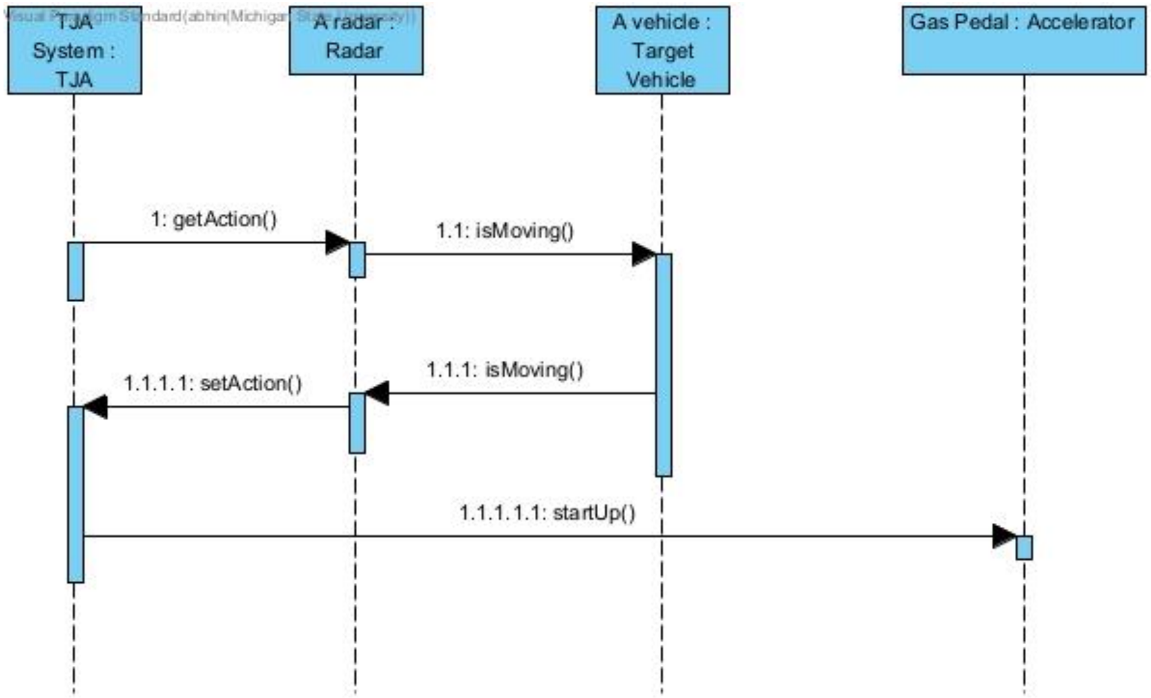


**Figure 5**: Scenario 3

**Figure 6**, below, shows the scenario of the TJA system deactivating when the driver wants to merge lanes. The lane following system will try to steer the vehicle back into the lane if the indicator is not applied. Once the indicator is applied, the lane following system will cause the TJA system to shut down because the vehicle is about to merge.

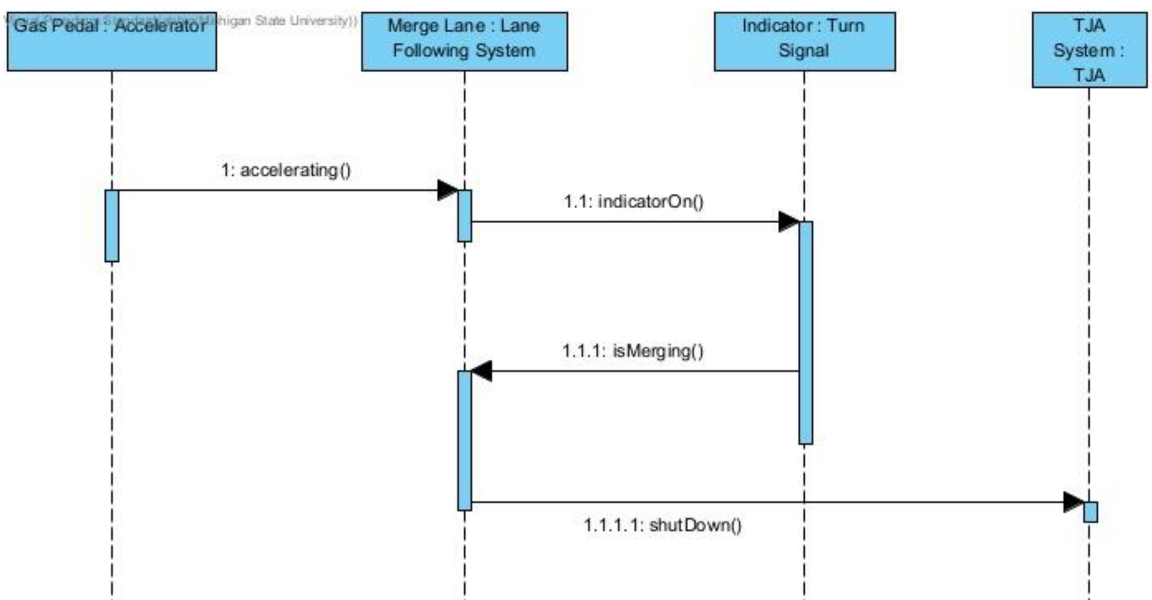


**Figure 6**: Scenario 4

**Figure 7**, below, shows the scenario of the TJA system shutting down due to a radar issue. The radar determines if the target vehicle is moving or not. If the radar is giving faulty information or is being blocked by inclement weather conditions, the TJA system shuts down.

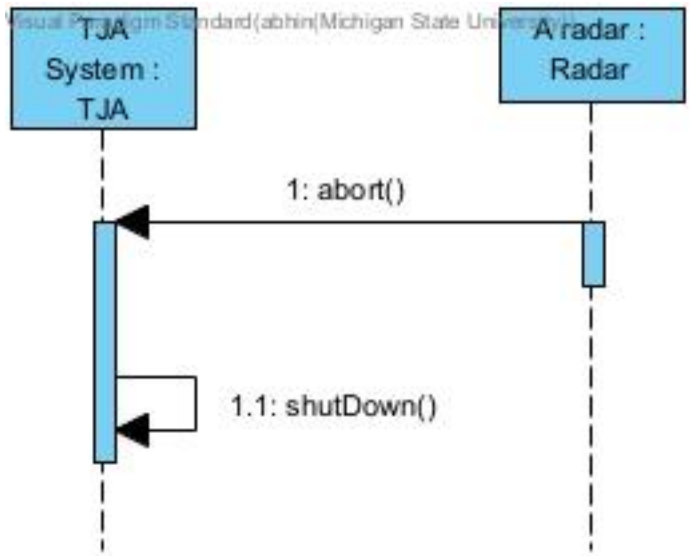


**Figure 7**: Scenario 5

**Figure 8**, below, shows the scenario of deactivating the TJA system. The GPS system lets the TJA system know its current location and traffic at that location, dictating when the TJA system should activate. If the GPS indicates that the vehicle is no longer on a limited access highway with traffic, the TJA shuts itself off.

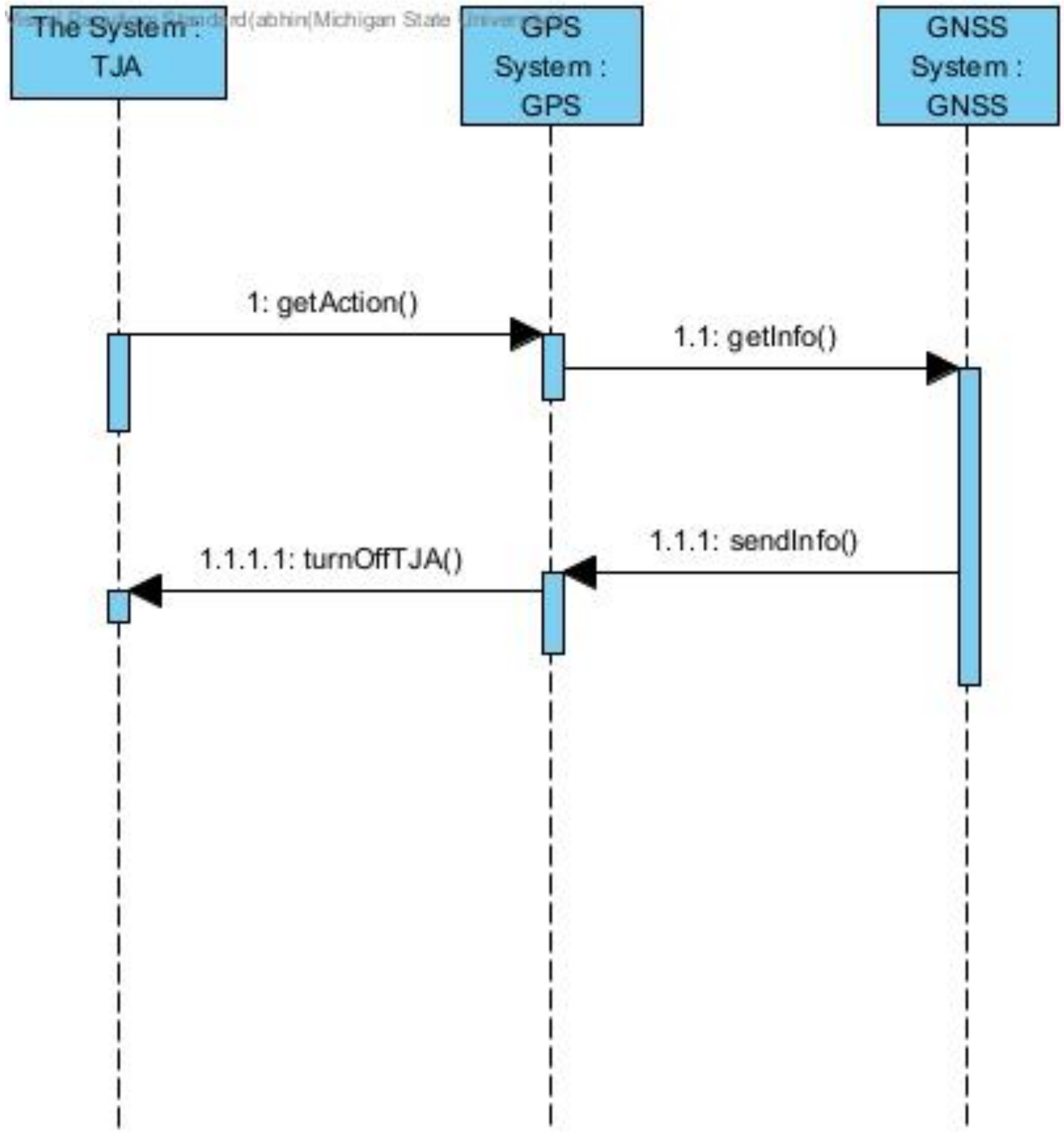


**Figure 8**: Scenario 6

## 4.4 State Diagram

In this section, state machines are illustrated to show how states change between the different components. State machines are, in fact, another method to understand scenarios.

**Figure 9**, below, the TJA system turns on only on limited access highways with traffic and turns off when it is no longer on highways with traffic. Additionally, the TJA system turns off if there are any issues with the radar. This state diagram references scenarios 1, 5, and 6.

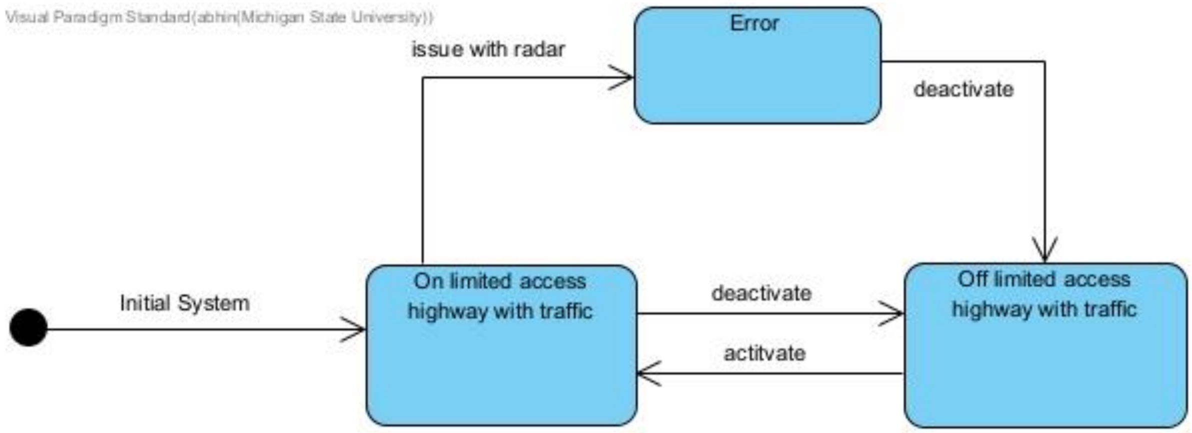


**Figure 9**: State Diagram of on/off

**Figure 10**, below, the TJA system initially adjusts to the traffic flow by stopping behind the idle target vehicle. Once the target vehicle starts moving, the driver's vehicle also starts following at a user set distance. Once the target vehicle starts coming to a stop, the driver's vehicle also starts coming to a stop. This state diagram references scenarios 2 and 3.

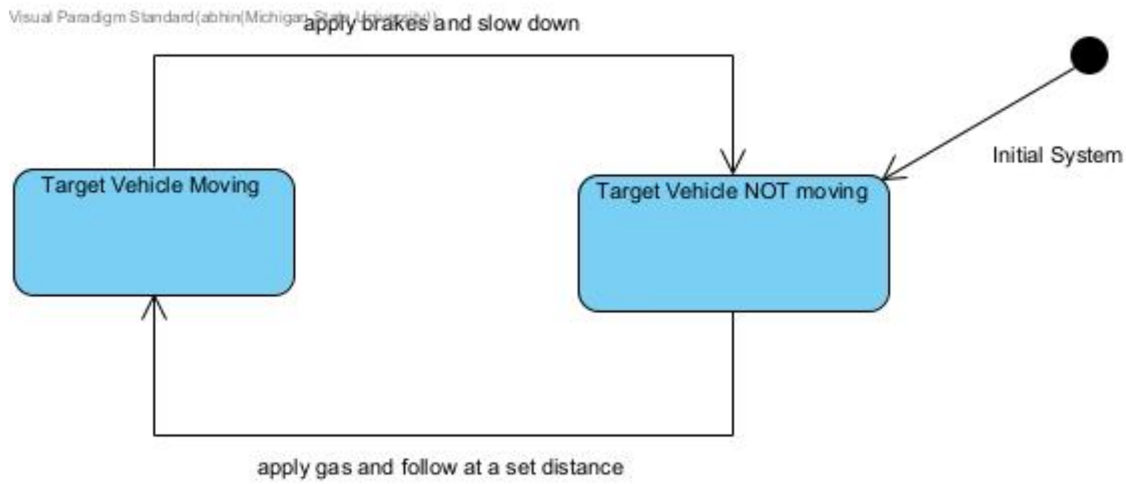


**Figure 10**: State Diagram of accelerator and brakes

**Figure 11**, below, the TJA system is initially already active. When the user decides to merge lanes by signaling, the TJA system will deactivate. When the vehicle is back in the center of its lane, the TJA system will activate. This state diagram references scenario 4.

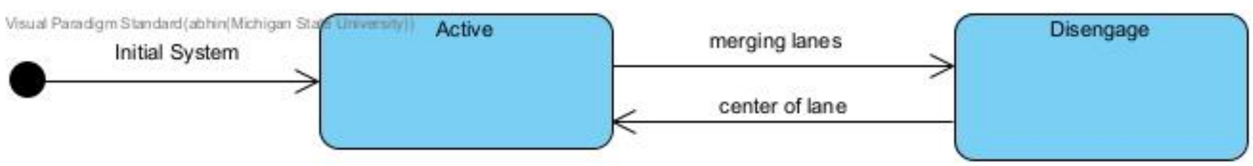


**Figure 11**: State Diagram of Lane Following

# 5 Prototype

This prototype shows how the TJA system performs in the scenarios mentioned above. The prototype will allow the reader of this document to have a visual reference to all the components of the TJA system and have a deeper understanding of the system.

## 5.1 How to Run Prototype

To access the prototype, go to https://www.cse.msu.edu/~gabbard3/Prototype/index.html. By clicking the link, the prototype will run in your browser. The prototype will work on all operating systems. However, it may take longer to load the prototype in some browsers. For example, the prototype may take upward of 3 minutes to run on Safari.

## 5.2 Sample Scenarios

**Figure 12**, below, is the scenario of activating the TJA system. The GPS system lets the TJA system know its current location and traffic at that location, dictating when the TJA system should activate. After activation, the TJA system turns on the forward-looking radar and determines the target vehicle in front of the driver's vehicle.

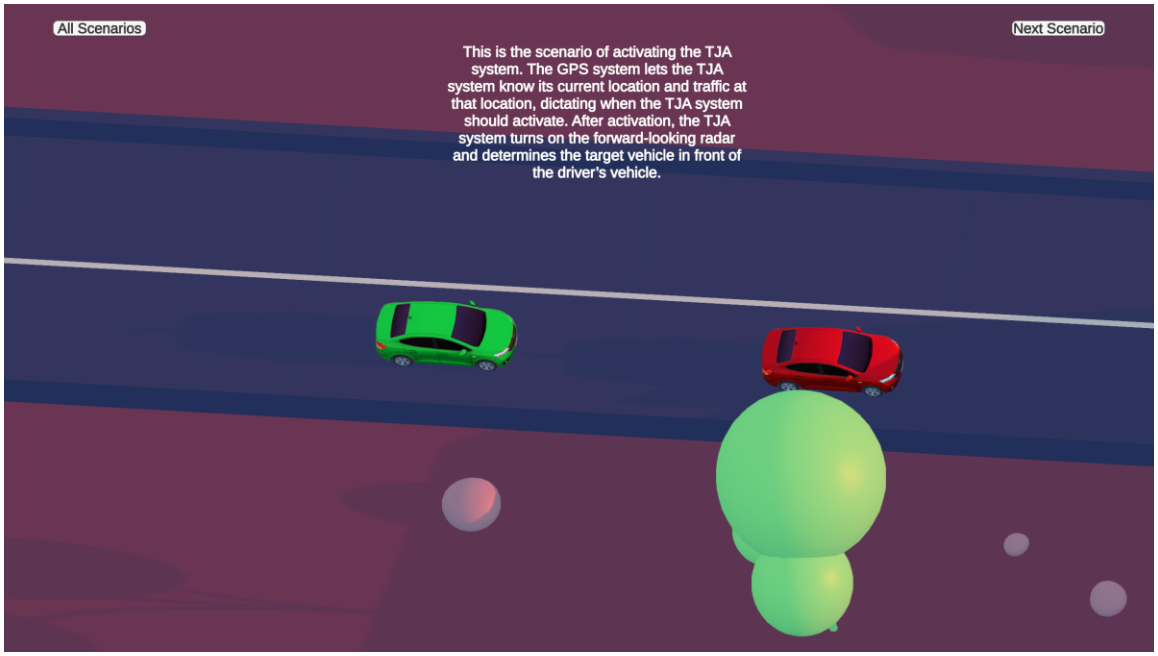


**Figure 12**: Scenario 1

**Figure 13**, below, shows the scenario of the TJA system slowing down the driver's vehicle and the scenario of the TJA system starting up the driver's vehicle. The radar determines if the target vehicle is moving or not. If the radar lets the TJA system know that the target vehicle is not moving, the TJA system engages the brakes to slow down and come to a stop. If the radar lets the TJA system know that the target vehicle is moving, the TJA system engages the accelerator to speed up and maintain a set distance to the target vehicle.

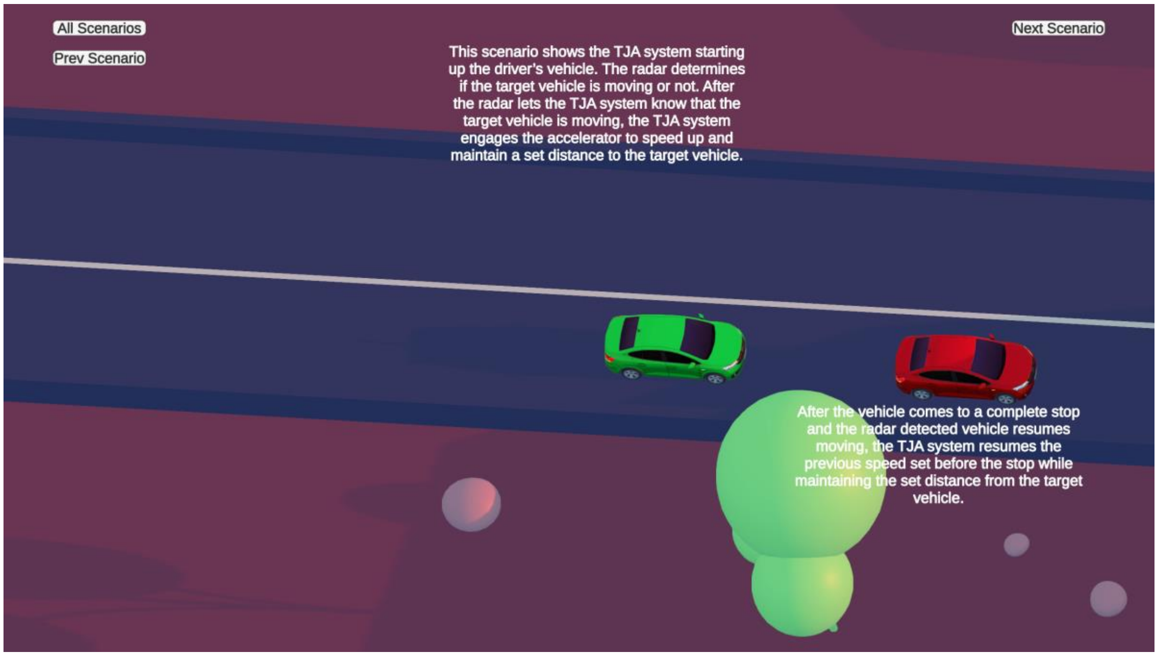


**Figure 13**: Scenario 2 and 3

**Figure 14**, below, shows the scenario of the TJA system deactivating when the driver wants to merge lanes. The lane following system will try to steer the vehicle back into the lane if the indicator is not applied. Once the indicator is applied, the lane following system will cause the TJA system to shut down because the vehicle is about to merge.

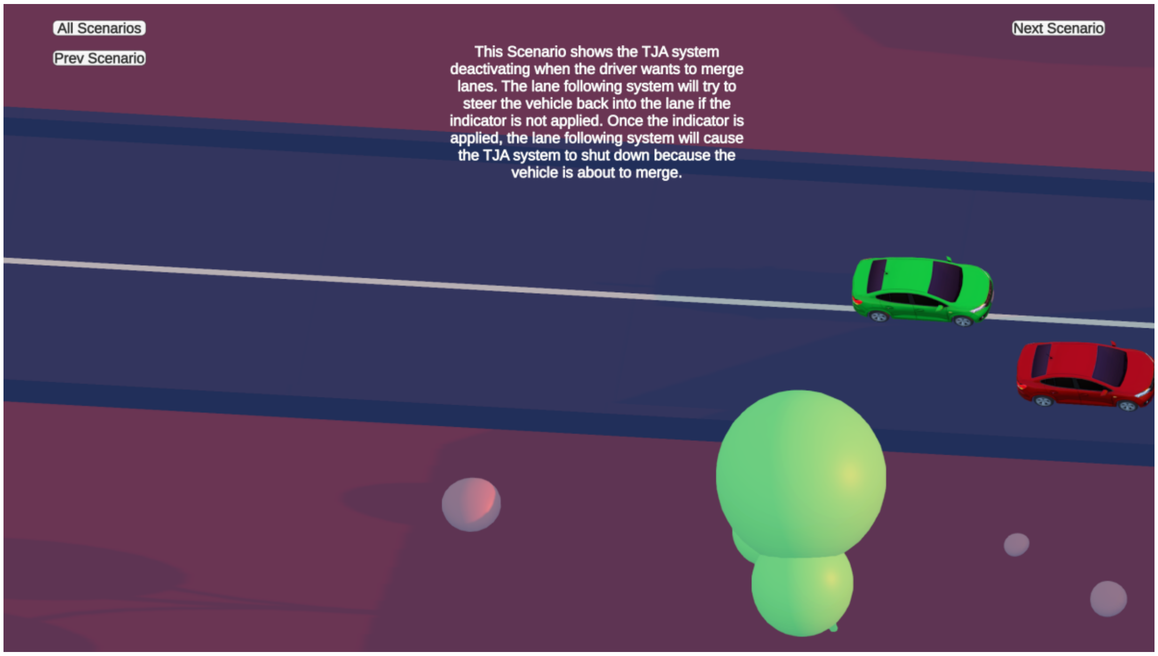


**Figure 14**: Scenario 4

**Figure 15**, below, shows the scenario of the TJA system shutting down due to a radar issue. The radar determines if the target vehicle is moving or not. If the radar is giving faulty information or is being blocked by inclement weather conditions, the TJA system shuts down.


**Figure 15**: Scenario 5

**Figure 16**, below, shows the scenario of deactivating the TJA system. If the GPS indicates that the vehicle is no longer on a limited access highway with traffic, the TJA turns itself off.

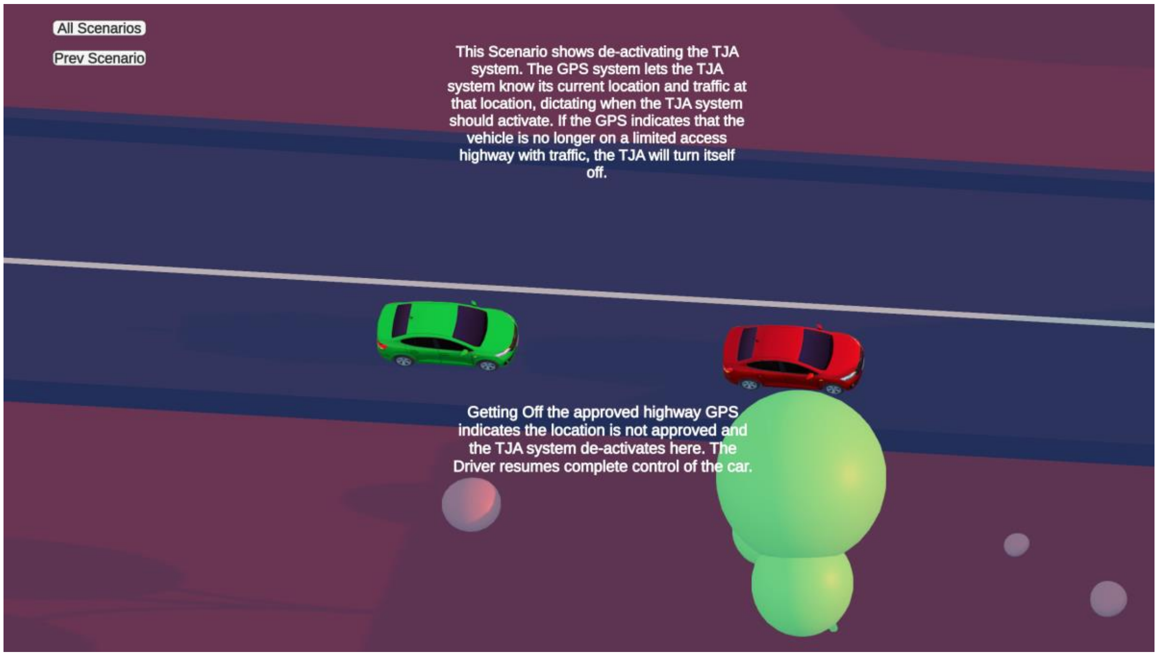


**Figure 16**: Scenario 6

# 6 References

[1] "What is GPS tracking and how does it work?", mixtelematics.com. [Online]. Available: https://www.mixtelematics.com/us/resources/blog/what-is-gps-tracking-and-how-does-it-work#:~:text=GPS%20Tracking%20System%20Basics,of%20the%20vehicle%20being%20tracked. [Accessed Oct. 28, 2022].

# 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.