Software Requirements Specification (SRS)

Project Traffic Jam Assist (TJA)

Team 4

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1 Introduction

Traffic Jam Assist (TJA) is a system that aims to expand upon Adaptive Cruise Control (ACC) by implementing several new features that ensure user safety. With TJA enabled, a user's vehicle can match the acceleration and deceleration of the vehicle directly ahead of it, minimizing human error in traffic jam driving.

In Section 1, we will introduce our software requirements specifications (SRS) and the overarching purpose of our specifications. Next, we will talk about the scope of our project in detail, addressing multiple components of TJA at a higher level, such as the benefits, the objectives, and the application domain. Lastly, we'll define common terminology needed to describe TJA and detail the organizational structure of our SRS document.

1.1 Purpose

To assuage any confusion about how TJA operates, this document will methodically go through every key component of the proposed system. After reading this document, any stakeholder should have a clear understanding of our system's core functionality, requirements, dependencies, constraints, and limitations, as well as visualize the application of our proposed system.

1.2 Scope

TJA is the next step in safety for the everyday driver. Previously pioneered by ACC, TJA seeks to expand upon ACC's robust framework, providing new features that will minimize human error while still prioritizing driver autonomy.

TJA is designed to reduce user error during traffic congestion on limited access highways. Upon engaging this system on specific TJA-compatible roads (like interstate highways), TJA locks onto the first vehicle directly ahead of the user's vehicle, detected via radar. Using radar, TJA then measures what is denoted as "closing rate." Closing rate is derived from the distance between the user's vehicle and the detected target vehicle. TJA has three different options for controlling relative distance. The closing rate grows if the distance between the two vehicles decreases and decreases if the distance increases. If the closing rate is positive, TJA decelerates the user vehicle to maintain the distance set. Otherwise, no action is needed, and speed is maintained. If the target decelerates, TJA matches the vehicle's deceleration. If both vehicles come to a stop, and then the target vehicle starts to move again, TJA follows suit. Throughout all of this, TJA implements Lane Keeping Assist System (LKAS), even without a target. If the user attempts to change lane while TJA is active without a turn signal, TJA deters the user but does not wholly prevent the user from merging.

1.3 Definitions, acronyms, and abbreviations

Adaptive Cruise Control (ACC) – A smart driving feature that uses sensors to automatically adjust a vehicle's speed to maintain a safe distance from the car ahead.

Bootstrap CSS – A popular front-end framework used for building responsive and mobile-first websites and web applications.

Closing Rate – The change in distance between the operating vehicle and the target vehicle over a period of time; this value is used by TJA to determine if the user vehicle should accelerate or decelerate to maintain the user set distance.

Computer Science and Engineering (CSE) – A discipline that combines the principles of computer science with the practical application of designing and developing computer systems and software.

GitHub – A platform and cloud-based service used by many software developers to store, manage, track, and control changes to their code.

Global Positioning System (GPS) – A navigation system that utilizes satellites to determine the precise location of targets.

Lane Keeping Assist System (LKAS) – The automotive feature that assists drivers by maintaining a central position in a marked traffic lane.

Software Requirements Specification (SRS) – A comprehensive document that outlines the detailed description of the functionalities, features, and behavior of a software system.

Traffic Jam Assist (TJA) – An advanced driver assistance system designed to enhance safety and convenience during congested traffic conditions. The system that this SRS document focuses on.

Unified Modeling Language (UML) – A standardized visual modeling language used in software engineering to depict, design, and document the structure and behavior of systems.

1.4 Organization

Now that TJA has been properly introduced, the rest of this document is dedicated to examining the specifics of the product. Section 2 will start with an overall description of the entire product, followed by Section 3, where an enumerated list of specific requirements that TJA relies on. Section 4 will visualize these requirements with the use of use case models, domain models, sequence diagrams, and state diagrams. Section 5 provides an interactive prototype of the system. Finally, Section 6 cites any references that have been used in this document, while Section 7 establishes a point of contact.

2 Overall Description

In Section 2, we will delve into detail describing key components of TJA. 2.1 starts with product perspective, where we will contextualize TJA and how it fits into the bigger picture, as well as describe constraints at a general level. Section 2.2 is product functions, which covers all of the major functions that TJA relies upon, while revisiting our customer specifications and displaying TJA's high-level goals. Section 2.3, user characteristics, will delineate what expectations TJA has of the user. All constraints will then be listed in Section 2.4, providing an in-depth description of all safety-critical properties (as well as other properties). Finally, section 2.5 documents all assumptions and dependencies, and section 2.6 details the apportioning of requirements, explicitly mentioning any requirements that fall outside the scope of TJA.

2.1 Product Perspective

TJA operates as part of an integrated system, relying on several embedded systems within the vehicle to function correctly. Since TJA measures distance between the user vehicle and a given target vehicle, TJA requires information from other embedded systems, as well as the ability to control others.

TJA has a few general constraints to the system. To measure distance between the user and the target, TJA requires access to the user vehicle's radar. Without information provided from the radar, there is no way that TJA can maintain a closing rate, and thus cannot function. It also needs access to this system to institute LKAS, for which TJA also needs access to the steering wheel to deter users from merging without signaling. Provided that TJA has access to radar, TJA needs some way to calculate a closing rate. Once the closing rate is obtained, TJA needs to be able to decelerate the vehicle, and possibly brake. As such, TJA needs to be able to send signals to the embedded systems responsible for acceleration and braking. Finally, if TJA is not enabled by the user via a toggleable control on the steering wheel, then TJA remains inactive.

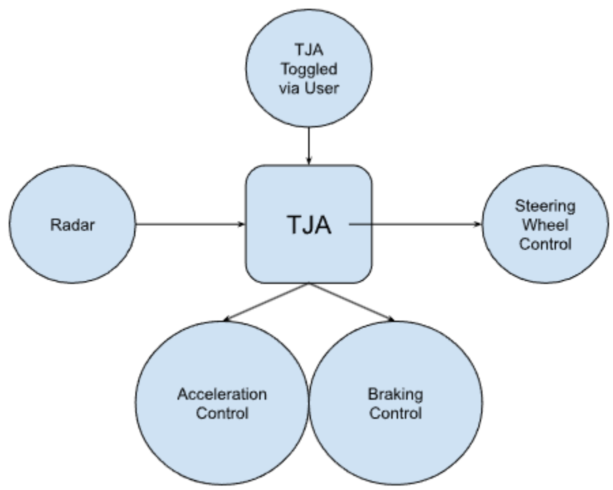

Figure 1: System Hierarchy

2.2 Product Functions

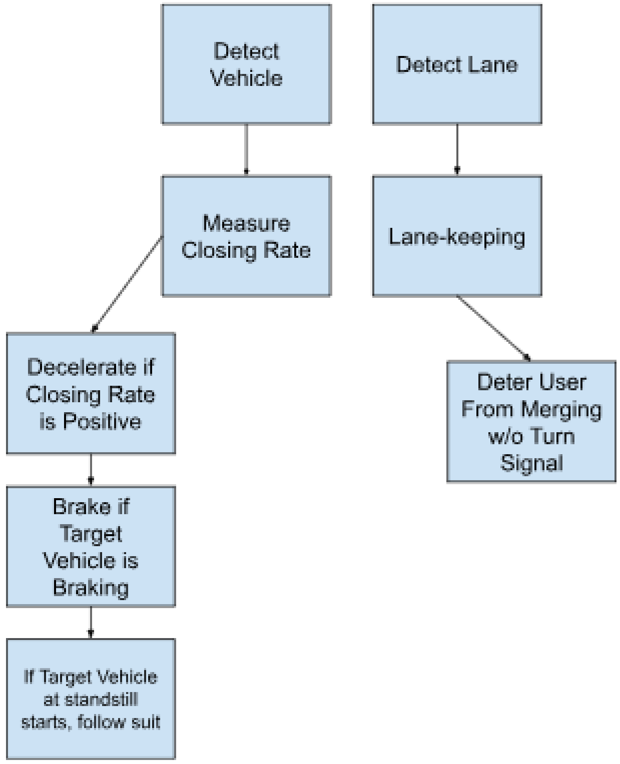

Figure 2: Goal Diagram

The TJA system enables the user to maintain a chosen distance from vehicles in front of the user. Utilizing a forward-facing radar, a target vehicle is identified, and the system adjusts the user's vehicle's acceleration and deceleration to achieve the desired distance. If the target vehicle decelerates to a full stop, TJA follows suit. When that same target vehicle resumes movement, TJA matches its acceleration and speed accordingly. Additionally, the system has LKAS functionality that uses a camera to track lane markings, ensuring the vehicle stays centered in its lane. Should the user attempt to change lanes without using the turn signal, lane changing won’t be prevented, but resistance is applied to the steering wheel to serve as an additional safety measure. TJA also maintains its functionality when passing through construction zones, and in these zones TJA acts no differently than it would on open roads. In situations where inclement weather is present, the TJA system continues to function as normal expect for extreme situations. Severe weather conditions that compromise the system's vision such as heavy rain or hail cause the system to automatically deactivate.

2.3 User Characteristics

The user of this system is expected to meet a few criteria. First, the user must possess the ability to operate an automotive vehicle and hold a valid driver's license. Without meeting these requirements, the system serves no purpose to the user. Since the system only exists to assist the driver of a vehicle, the user must be a competent driver as well, capable of making informed decisions while operating the vehicle. While this system aims to mitigate human error, it is not all encompassing. To activate the system the user must have a basic understanding of how their vehicles systems work. Familiarity with features like cruise control and the ability to activate such systems qualifies users for utilizing the TJA system. Additionally, users need to be well-informed about how TJA functions to ensure seamless compatibility and optimal use of the proposed system.

2.4 Constraints

Any property that is safety-critical is defined as a system whose failure could result in loss of life, significant harm to a person, severe proprietary damage, and/or environmental damage. [2] TJA relies on other systems to operate at their fullest capacity. Should some of these systems fail, the safety of the user, as well as that of other individuals and property in the vicinity of the user's vehicle, could be compromised. The safety critical systems encompass radar systems, cameras, embedded systems responsible for acceleration, deceleration, and braking, as well as those responsible for steering wheel assistance. If any of these systems were to malfunction in any capacity, TJA would not be able to perform in a manner that would guarantee safety. For instance, should the radar system fail, TJA loses its ability to measure closing rate, and maintain adequate space between vehicles. In situations where the camera fails such as extreme inclement weather, TJA would not be able to implement LKAS. Similarly, if the embedded systems for steering wheel assistance were to malfunction, TJA would have no way of enforcing LKAS. If the embedded systems responsible for acceleration, deceleration, and braking were to fail, TJA's ability to maintain safe distances between vehicles would be rendered useless. Without the proper functioning of these essential systems, TJA lacks the fundamental capabilities required for safe and effective operation. Therefore, it cannot be deemed operational or functional in its intended capacity. The absence or malfunction of these systems critically impairs TJA's ability to perform its designated functions, compromising its reliability and rendering it unsuitable and unsafe for use.

2.5 Assumptions and Dependencies

The effectiveness of the TJA system relies significantly on specific assumptions about the user and their vehicle, forming the cornerstone of its functionality. Its primary assumption is that the user is fully capable of operating a motor vehicle. TJA also makes multiple assumptions pertaining to its vehicle's health. It operates under the assumption that the vehicles radar, camera, brakes, and other core components of a vehicle exist and are fully functional. Similarly, TJA assumes acceptable and manageable levels of fuel and tire pressure. At a very simple level, TJA assumes that the user knows how to activate it. In essence, these assumptions form the bedrock of TJA's functionality, pivotal for its reliable operation.

The TJA system is intricately reliant on specific dependencies to make its design and functionality possible. Primarily, TJA operates on the premise of assisting rather than replacing the user, hence depending on the user to be capable of correctly operating a motor vehicle. Should a user be unable to operate their vehicle, TJA loses all utility. Similarly, TJA fully depends on the existence and proper functioning of crucial components like cameras, radar, and brakes within the vehicle. Consequently, TJA's operational success is dependent on the functionality of these physical components. Additionally, TJA's functionality depends on the user's familiarity with its activation process as without this knowledge, the system remains inactive. The system’s performance also depends on the presence of a target vehicle in front of the operating vehicle. If no target vehicle is detected, TJA reverts to an ACC system. These dependencies collectively underscore the critical aspects upon which TJA relies for its optimal operation and effectiveness.

2.6 Apportioning of Requirements

TJA serves as a smaller portion of a larger end goal that would realize partial/full autonomous driving. As such, there are many features that could ideally be folded into TJA, that shouldn’t be at this time. TJA currently only operates on a limited selection of carefully selected roads – any plans to extend this functionality to roads that are not mapped out on a GPS, or are not included in this list, go beyond this project’s current scope. Any plans to have TJA detect road signage (such as stop signs, yield signs, traffic lights, etc.) go beyond this project’s current scope. There are no current specifications for TJA to handle autonomous lane-merging, all these features can be considered for future versions of TJA, but at this time are not in line with this project’s current specifications.

3 Specific Requirements

3.1 Global Invariant Requirements:

1. The system only operates on limited access highways verified by GPS.
2. The TJA system turns off when the driver hits the brakes.
3. Using the radar, the system detects new objects that come in between the target vehicle and the operating vehicle and sets the new object as the target vehicle.
4. The TJA system constantly monitors the speed of the operating vehicle and deactivates if the user vehicle’s speed exceeds 40kph.
    a. Monitoring is needed so that the operating vehicle may adjust its speed accordingly to the flow of traffic which ensures the safety of the passengers and to prevent traffic from building up.

3.2 Primary Requirements:

1. TJA activates at a set target speed when user presses button on the steering wheel.
    a. The set target speed is the speed the vehicle will maintain if there are no target vehicles in range.
2. TJA identifies objects in front of the operating vehicle.
3. The system keeps the vehicle in motion following the flow of traffic at a set distance.
    a. The operating vehicle maintains a set distance of 10, 15, or 20 meters between the operating vehicle and the vehicle in front which are close, medium, and far respectively.
    b. The system accelerates or decelerates the operating vehicle until the closing rate is 0 to match the speed of the target vehicle when the distance between the two is equal to the set distance.
    c. If the target vehicle accelerates or decelerates, the operating vehicle follows suit.
    d. If the target vehicle is stopped, the operating vehicle must stop.
    e. If the closing rate between the two vehicles is negative, the car must be able to decelerate.
4. If the targeted vehicle switches lanes or exits the road and no new target vehicle is detected, the system alerts the driver with a flashing icon on the dashboard before disabling the system and activating ACC the speed set by the driver.
5. The operating vehicle resumes travel at the user’s chosen (set) speed upon two requirements:
    a. When the lane is changed.
    b. When there is no vehicle detected ahead.
6. The system refuses to operate if it detects that the camera or radar is inoperable in any way.

3.3 Secondary Requirements:

1. For the TJA system to operate, the driver must always have their hands on the wheel.
    a. Upon having their hands off the wheel, the driver will be alarmed with a sound cue and a flashing icon on the dashboard by the TJA system.
2. If the driver has not had their hands on the wheel for longer than 30 seconds, the system alerts the driver with a sound cue and a flashing icon on the dashboard and deactivates after another 30 seconds have passed.
3. The vehicle deactivates the system and requires the driver to re-activate it in the event where the operating vehicle has stopped for longer than 30 seconds.
4. The TJA system ensures that the operating vehicle is in the middle of the lane using LKAS.
5. The TJA system adjusts to uphill and downhill conditions to maintain set distance.
6. The system warns the driver with a sound cue and a flashing icon on the dashboard if the road is not a verified limited access highway.

7. The system keeps the closing rate between the operating vehicle and the vehicle in front as close to 0 as possible.
8. The system discourages lane changing without signaling.
    a. Uses the front facing camera to detect if the vehicle is getting close to a lane line.
    b. If a turn signal is not on, the system uses LKAS to nudge the steering wheel back slightly.

3.4 Security Requirements:

1. The TJA system and all its components must not have any form of wireless connectivity, including but not limited to: Internet, Bluetooth, and Radio to prevent external threats.
2. The TJA system must be able to monitor its components to ensure that they are functioning properly. If a component is not functioning, the TJA system should notify the operator and refuse to activate.
3. The TJA system must encrypt its communications with all its components to ensure they cannot be intercepted and modified by a third party.
    a. If the TJA system detects unencrypted or improperly encrypted communications with its components, it must alert the operator and deactivate. The TJA system should refuse to activate until serviced by an appropriate technician.

4 Modeling Requirements

This section will visualize different parts of the TJA system and its aspects using several different diagrams. This section will examine our relevant use case diagrams, object-oriented domain model, sequence diagrams, and state diagrams.

4.1 Use Case Diagram

The use case diagram, pictured below, displays and describes the major use cases between the user and the target object ahead. The car drawn on the left side of the figure represents the user of the TJA system. The user, as a part of the vehicle, is able to control different actions regarding the TJA system. A line connects the user vehicle to different actions and cases. On the right side of Figure 3, the vehicle represents the target vehicle that the TJA system may be interacting with.

In between the two vehicles lies a series of use cases, that all lie within a system boundary. The system boundary outlines what scenarios are included within TJA's functionality. These use cases either influence the TJA system within the vehicle or change how the system operates in relation to the target vehicle. For example, if there is a line connecting a use case with the target, that indicates that the system changes how it interacts with the target, such as slowing down if necessary. If a use case does not connect to the target, it is a driver-induced case, such as activating the system, or braking for example.

Below this figure is a detailed description of each use case and how they affect the TJA system.

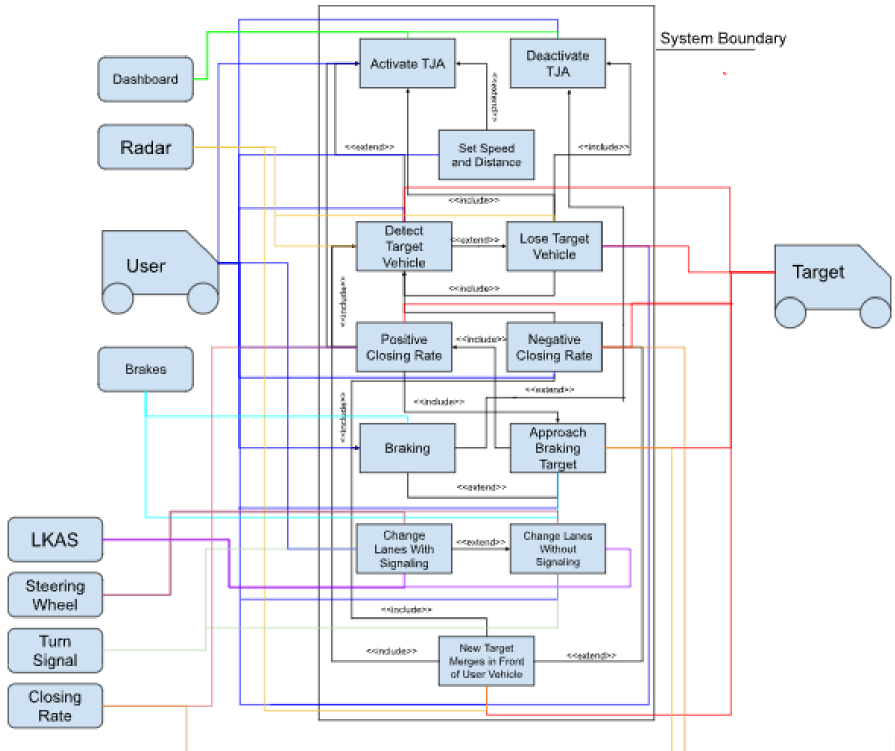

Figure 3: Use Case Diagram

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Actor Color
User
Target
Dashboard
Radar
Brakes
LKAS
Steering Wheel
Turn Signal
Closing Rate

Figure 3a: Use Case Diagram – Actor Color Scheme

Table 1: Activate TJA

Use Case:	Activate TJA
Actors:	User, Dashboard
Description:	Activate TJA
Type:	Primary

Includes:	None
Extends:	None
Cross-refs:	Requirements: 3.1.1, 3.1.4, 3.2.4, 3.3.1
Use cases:	Set Speed and Distance Detect Target Vehicle Lose Target Vehicle Change Lanes without Signaling Change Lanes with Signaling Approach Braking Target Braking Positive Closing Rate Negative Closing Rate New target Merges in front of User Vehicle

Table 2: Deactivate TJA

Use Case:	Deactivate TJA
Actors:	User, Dashboard
Description:	Deactivate TJA
Type:	Primary
Includes:	None
Extends:	None
Cross-refs:	Requirements: 3.1.1, 3.1.2, 3.2.4, 3.3.1, 3.3.1a, 3.3.2, 3.3.3, 3.4.2, 3.4.3a
Use cases:	Detect Target Vehicle Lose Target Vehicle Change Lanes without Signaling Change Lanes with Signaling Approach Braking Target Braking Positive Closing Rate Negative Closing Rate New Target merges in front of User Vehicle

Table 3: Set Speed and Distance

Use Case:	Set Speed and Distance
Actors:	User, Dashboard
Description:	Upon Enabling TJA, the User will set their vehicle's speed and distance
Type:	Primary
Includes:	None
Extends:	Activate TJA
Cross-refs:	Requirements: 3.1.4, 3.2.1, 3.2.3a, 3.2.5
Use cases:	Positive Closing Rate Negative Closing Rate

Table 4: Detect Target Vehicle

Use Case:	Detect Target Vehicle

Actors:	User, Target Vehicle, Radar
Description:	The system should detect when there is a target present in its field of vision in front of the operating vehicle. If a target can be tracked, then the operating vehicle should choose that vehicle as its target.
Type:	Primary
Includes:	None
Extends:	Activate TJA
Cross-refs:	Requirements: 3.1.3, 3.2.2, 3.2.4
Use cases:	Braking Positive Closing Rate Negative Closing Rate New target Merges in front of User Vehicle

Table 5: Lost Target Vehicle

Use Case:	Lose Target Vehicle
Actors:	User, Target Vehicle, Radar
Description:	The system should detect when a target has been lost in its field of vision in front of the operating vehicle. If the target cannot be tracked, then the operating vehicle should lose that target.
Type:	Primary
Includes:	Activate TJA, Deactivate TJA, Detect Target Vehicle
Extends:	Detect Target Vehicle
Cross-refs:	Requirements: 3.2.4
Use cases:	Change Lanes with Signaling Change Lanes without Signaling New target Merges in front of User Vehicle

Table 6: Braking

Use Case:	Braking
Actors:	User, Brakes
Description:	Slow the vehicle down with brakes
Type:	Primary
Includes:	None
Extends:	Deactivate TJA
Cross-refs:	Requirements: 3.1.2
Use cases:	Approach Braking Target Positive Closing Rate Negative Closing Rate New target Merges in front of User Vehicle

Table 7: Change Lanes with Signaling

Use Case:	Change Lanes with Signaling

Actors:	User, LKAS, Steering Wheel, Turn Signal
Description:	A driver, who needs to change lanes, will use their turn signal to indicate they need to change lanes. If the turn signal is used, the TJA lane assist will not move the steering wheel to prevent lane change
Type:	Secondary
Includes:	None
Extends:	None
Cross-refs:	Requirements: 3.3.8, 3.3.8a
Use cases:	None

Table 8: Change Lanes without Signaling

Use Case:	Change Lanes without Signaling
Actors:	User, LKAS, Steering Wheel, Turn Signal
Description:	The system should contact the driver via the steering wheel by attempting to turn the wheel back towards the lane the vehicle is currently in. The goal of this is to alert the driver if the car begins drifting into another lane unintentionally.
Type:	Secondary
Includes:	None
Extends:	Changing Lanes with Signaling
Cross-refs:	Requirements: 3.3.8b
Use cases:	None

Table 9: Approach a Braking Target

Use Case:	Approach Braking Target
Actors:	User, Target Vehicle, Closing Rate
Description:	The primary vehicle follows behind the target vehicle. As the target vehicle begins to brake, the Traffic Jam Assist system automatically slows the primary vehicle maintaining the set distance to the best of its ability.
Type:	Primary
Includes:	Positive Closing Rate
Extends:	Braking
Cross-refs:	Requirements: 3.2.3b, 3.2.3c, 3.2.3d, 3.2.3e, 3.3.7
Use cases:	None

Table 10: Positive Closing Rate

Use Case:	Positive Closing Rate
Actors:	User, Target Vehicle, Closing Rate
Description:	When the operating vehicle detects a target vehicle while Traffic Jam Assist is active, the operating vehicle calculates a closing rate. When the system calculates that the closing rate is positive (I.e. the vehicles are getting farther to one another), the system maintains the set speed at the set distance
Type:	Primary
Includes:	Approach Braking Target Detect Target Vehicle Activate TJA
Extends:	None
Cross-refs:	Requirements: 3.1.3, 3.1.4, 3.2.2, 3.2.3, 3.2.3b, 3.2.3c, 3.2.3d, 3.2.3e, 3.3.7
Use cases:	Braking

Table 11: Negative Closing Rate

Use Case:	Negative Closing Rate
Actors:	User, Target Vehicle, Closing Rate
Description:	When the operating vehicle detects a target vehicle while Traffic Jam Assist is active, the operating vehicle calculates a closing rate. When the system calculates that the closing rate is negative (the vehicles are getting closer to one another) the system slows down the operating vehicle in order to maintain the set distance.
Type:	Primary
Includes:	Detect Target Vehicle Braking
Extends:	None
Cross-refs:	Requirements: 3.1.3, 3.1.4, 3.2.2, 3.2.3, 3.2.3b, 3.2.3c, 3.2.3d, 3.2.3e, 3.3.7
Use cases:	Approach Braking Target

Table 12: Merging

Use Case:	New Target Merges in Front of User Vehicle
Actors:	User, Target Vehicle, Radar
Description:	If TJA is activated, regardless of if a target has already been defined or not, TJA must readjust to target the new vehicle that has suddenly merged in front of the user vehicle.
Type:	Secondary

Includes:	Detect Target Vehicle Braking
Extends:	Negative Closing Rate
Cross-refs:	Requirements: 3.1.3, 3.2.2, 3.2.3, 3.3.7
Use cases:	None

4.2 Domain Model

Figure 4, displayed below, depicts an object-oriented model intended to describe the system domains. This diagram uses UML to notate classes and their relationships, operations, and attributes. In this diagram, the class Target, for example, references the target object that radar detection has identified. Target has an attribute, distance, indicates the distance from the operating vehicle to the object ahead. It does this using the function "calculate_distance()". The Target has a relationship with the class Road Object through an aggregation, which has an outlined diamond shape. This relationship indicated that the Road Object is a part of the Target. Other relationships seen in this diagram include a generalization. A generalization indicates that one class shares characteristics of a more general class. Additionally, composition is a relationship between two classes, displayed using a filled-in diamond shape. Composition indicates that one class contains another class. This can be seen with the operating vehicle containing steering, a camera, and radar detection. Every class in this diagram includes a detailed summary below the figure indicating its attributes, operations, and relationships.

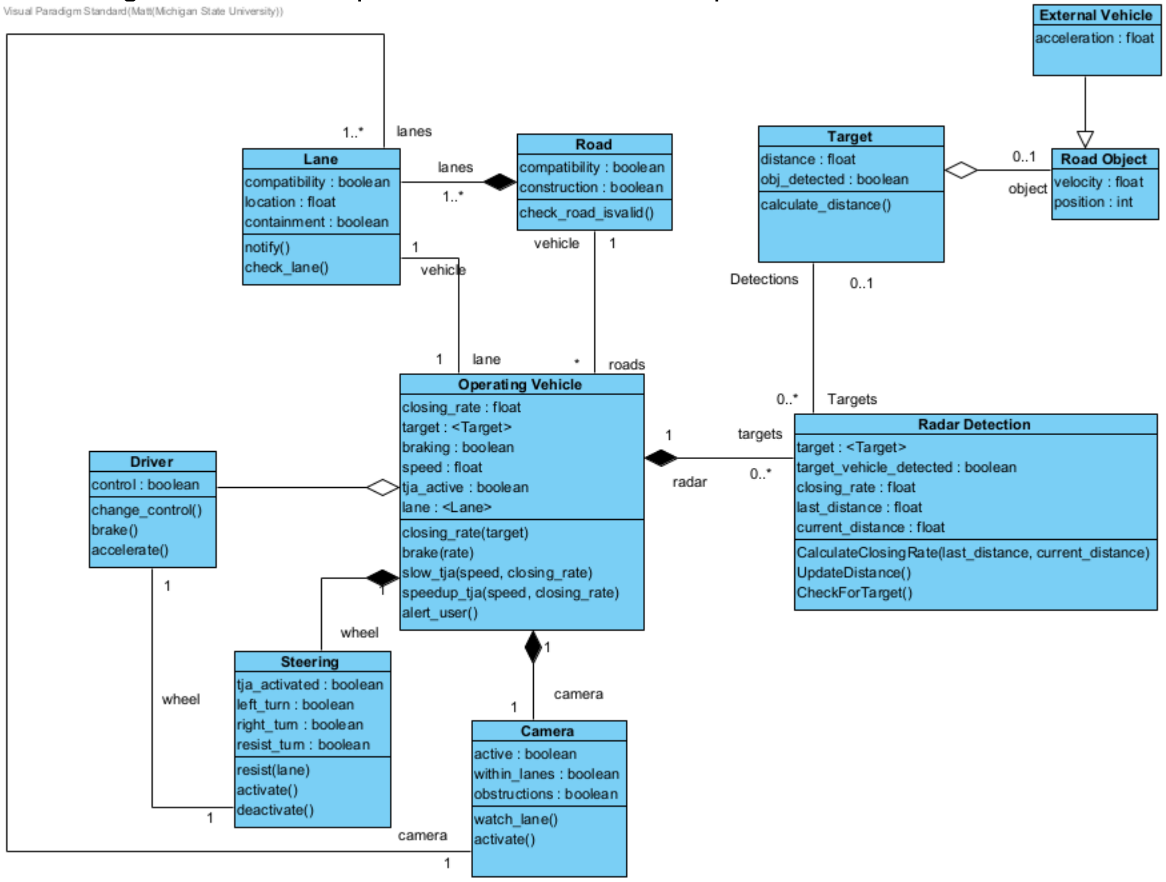

Figure 4: Domain Model

Table 13: Camera Class

Element Name		**Description**
Camera		The camera connected to the operating vehicle. It constantly watches the lanes of the road
Attributes		
	Active : Boolean	Whether or not the camera is on
	Within_lane : Boolean	Whether or not the vehicle is properly in the lane
	Obstructions : Boolean	Whether the camera detects obstructions within the road
Operations		
	Watch_lane() : Boolean	Continuously called to check to see if the vehicle is within the lanes. Should continuously return true until the vehicle is out of the lane
	Activate() : Void	Activates and deactivates the camera

Relationships	Associations with Lane and Operating vehicle

Table 14: Driver Class

Element Name		Description
Driver		The driver of the vehicle, human person. This person has the ability to activate the TJA features of the vehicle they are operating
Attributes		
	Control : boolean	Whether the TJA is on or off
Operations		
	Change_control() : void	Changes the control variable. Turns TJA on or off
	Brake() : void	Called when the driver presses the brake, turns off TJA
	Accelerate() : void	Called when the driver manually accelerates, turns off TJA
Relationships	Association with Steering. Aggregation with Operating Vehicle	

Table 15: External Vehicle Class

Element Name		Description
External Vehicle		An object on the road that is designated as a vehicle rather than other objects
Attributes		
	Acceleration : float	The acceleration of the external vehicle
Relationships	Generalization of road object	

Table 16: Lane Class

Element Name		Description
Lane		The lane the operating vehicle is currently in
Attributes		
	Compatibility : Boolean	Whether the lane is compatible with the TJA system
	Location : float	The location of the operating vehicle within the lane
	Containment : Boolean	If the vehicle is currently and properly within the lane
Operations		
	Notify() : Boolean	Notify the user if the vehicle leaves the lane, returns a Boolean to indicate leaving the lane

	Check_lane() : Boolean	Function that continuously runs to check and see if the vehicle is within the lane. Updates the Containment variable
Relationships	Associations with Road, Operating Vehicle, and Camera	

Table 17: Operating Vehicle Class

Element Name		Description
Operating Vehicle		The operating vehicle is at the center of the TJA system. It olds all of the vehicle information and performs the necessary operations provided by the TJA system
Attributes		
	Closing_rate : float	The closing rate between the target and the operating vehicle
	Target : <Target>	The target object. Could be a vehicle or road obstruction
	Braking : Boolean	Whether the vehicle is currently braking
	Speed : Float	The speed of the operating vehicle
	Tja_active : Boolean	Whether the TJA system is activated
	Lane : <Lane>	The lane that the vehicle is in
Operations		
	Closing_rate(target : <Target>) : float	Calculates the closing rate with the target object
	Brake() : Void	Called when the user uses the brake
	Slow_tja (speed : float, closing_rate : float) : Void	Slows down the vehicle in accordance with the closing rate and changes the current vehicle speed
	Speedup_TJA (speed : float, closing_rate : float) : Void	Speeds up the vehicle in accordance with the closing rate of the target (if applicable) and changes the current vehicle speed
	Alert_user() : Void	Creates an alert for the user for a variety of reasons. This alert can be used to notify steering about moving out of a lane or if there is a TJA issue
Relationships	Associations with Lane, Steering, Camera, and Radar Detection	

Table 18: Radar Detection

Element Name	Description
Radar Detection	Radar detection will be used by the operating vehicle to detect and identify a target vehicle for the Traffic Jam Assist system. It then determines the

		closing rate from the operating vehicle to the target vehicle and informs the system of this rate
Attributes		
	Target : <Target>	The target that the radar is locked on to
	Target_vehicle_detected : Boolean	Whether a target is detected by the radar
	Closing_rate : float	The closing rate between the operating vehicle and the target
	Last_distance : float	The previous calculated distance from the radar, used to calculate the closing rate
	Current_distance : float	The current distance between the operating vehicle and the target
Operations		
	calculateClosingRate(Last_distance, current_distance) : float	Calculates the closing rate between the target and the operating vehicle
	UpdateDistance() : void	Updates the distance variables Last_distance and Current_distance
	CheckForTarget() : void	Uses the radar to check for a target, updates Target and Target_vehicle_detected
Relationships	Associations with Operating Vehicle and Target	

Table 19: Road Class

Element Name		**Description**
Road		The road on which the operating vehicle is currently driving. Can contain things like construction. Checks if the road is calid or compatible for use with the TJA
Attributes		
	Compatibility : Boolean	If the road is a TJA is compatible with the TJA system
	Construction : Boolean	If the GPS within the vehicle indicates that there is construction on the road
Operations		
	Check_road_isvalid( ) : Void	Checks if the road is valid using the vehicles GPS. Updates the compatibility and construction variables
Relationships	Associations with Lane and Operating Vehicle	

Table 20: Road Object Class

Element Name		Description
Road Object		An object in front of the vehicle. A classification created by a Target. It can either be an object, such as a construction barrel, or an External Vehicle
Attributes		
	Velocity : float	The speed at which this object is moving
	Position : float	How far away this object is from the operating vehicle
Relationships	Aggregation of target	

Table 21: Steering Class

Element Name		Description
Steering		Steering will be used to allow the driver to control the left to right movement of the vehicle
Attributes		
	Tja_activated : Boolean	Whether the TJA is activated
	Left_turn : Boolean	If the driver is turning left
	Right_turn : Boolean	If the driver is turning right
	Resist_turn : Boolean	If the steering wheel is currently resisting a turn due to TJA
Operations		
	Resist(Lane : <Lane> : void	Resist the turn if the vehicle is out of the lane without a turn signal
	Activate() : Void	Activate the resistance feature
	Deactivate() : Void	Deactivate the resistance feature
Relationships	Associations with Operating Vehicle and Driver	

Table 22: Target Class

Element Name	Description
Target	A vehicle or road object in front of the operating vehicle used for determining the target speed of the operating vehicle based on the distance from the operating vehicle to the target

Attributes		
	Distance : float	The distance between the road object and the operating vehicle
	Obj_detected : Boolean	Whether a road object is detected and set as the target
Operations		
	Calculate_distance() : float	Calculates the distance between the road object and the operating vehicle and returns that distnace
Relationships	Association with Radar Detection	

4.3 Sequence Diagram

This section will be used to display and describe TJA sequence diagrams. For each diagram, the large blue boxes with dotted lines represent different changes in the environment or within the TJA system. The lines connecting the large blue boxes describe how the TJA system will operate to bring it to that next position. The operations may skip steps to get to certain endpoints. Additionally, certain operations may reach a single endpoint as well.

Figure 5 below represents system activation. The TJA system, when off, requires manual activation. Activation is controlled within the steering wheel of a vehicle. The application is activated using a button on the steering wheel, which then calls a function Activate() to activate the complete TJA system within the vehicle. Conversely, Deactivate() deactivates the system.

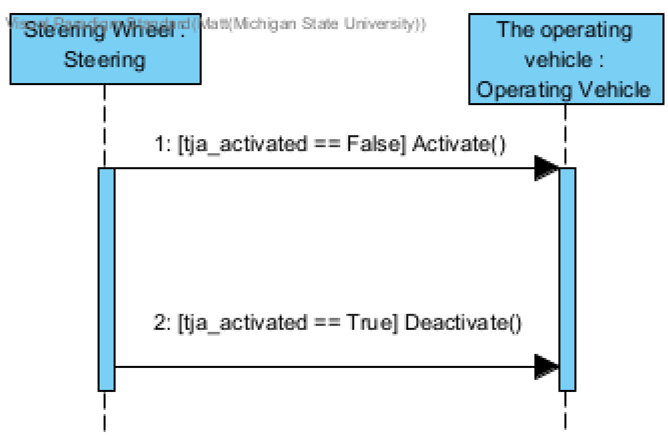

Figure 5: TJA Activation

Figure 6 below illustrates the relationship between the vehicle, radar, and the target vehicle. If the TJA system is active, the function to calculate the closing rate is called by the radar detection. Radar detection, if a target vehicle is present, calculates a closing rate using the location of the target and its last distance. Radar detection only calculates closing rate if the TJA system has already been activated by the user.

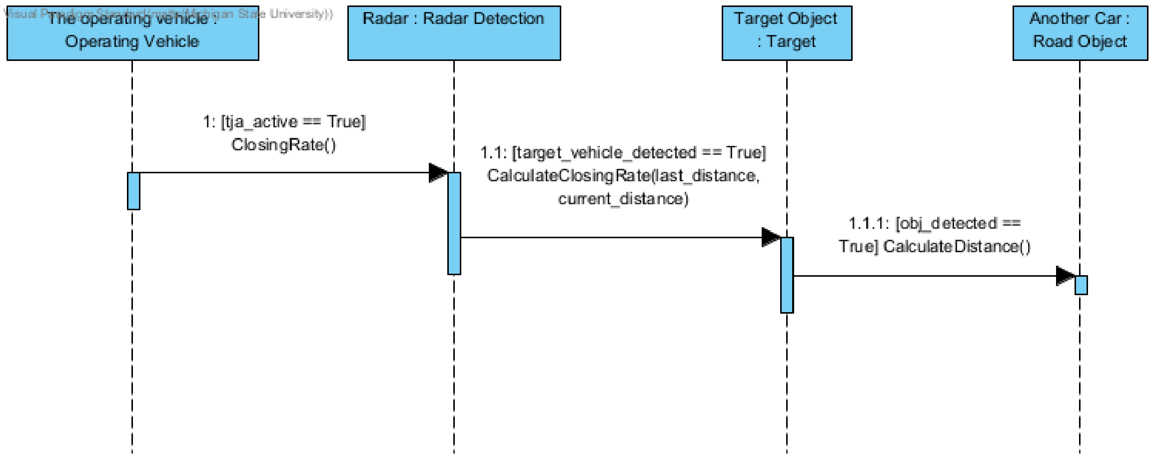

Figure 6: Object Detection

Figure 7 below describes how the TJA system continuously checks to see the closing rate and perform actions to the vehicle as needed. For example, if the closing rate is negative, the TJA system makes a call for the vehicle to slow down, to reach a closing rate of zero. Oppositely, if the closing rate is positive, the TJA system calls for the vehicle to accelerate to reach a closing rate of zero. The system continuously checks the closing rate to the target to evaluate the safe action to take.

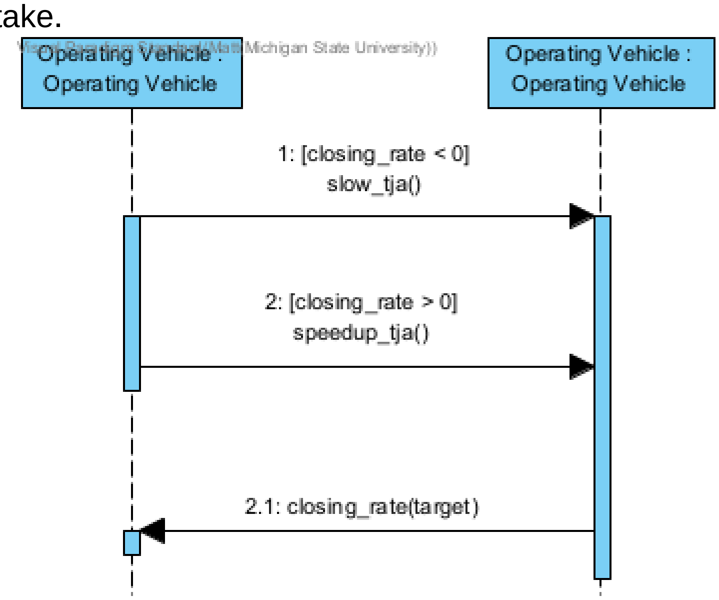

Figure 7: Accelerate and Decelerate

Figure 8 below illustrates the relationship between the TJA system and lanes on the road. The operating vehicle, when the TJA is active, activates the camera within the vehicle. The camera then maintains a visual on the lane of the road that the is on. If the system notices that the vehicle is changing lanes, it sends an alert back to the vehicle that causes an action from the steering wheel such as physical resistance.

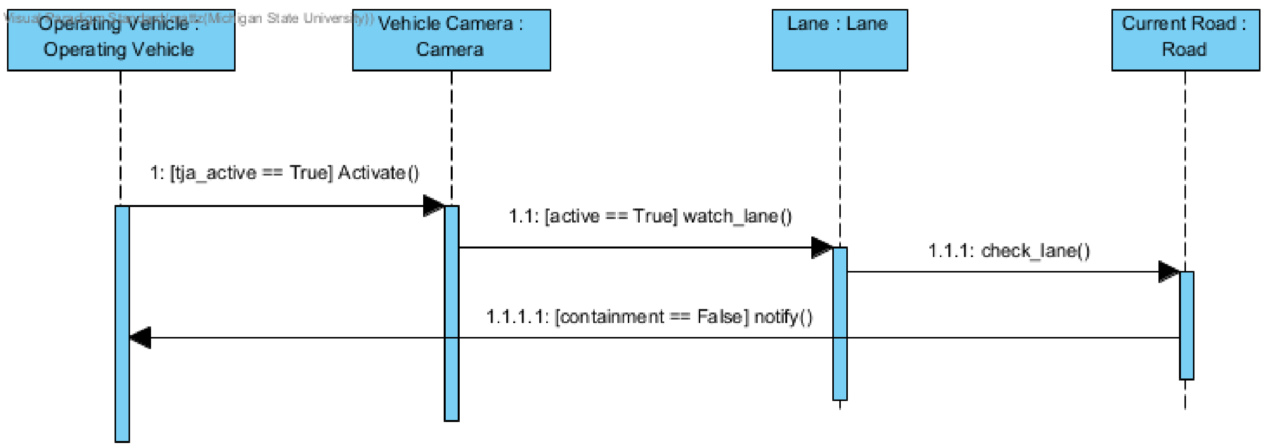

Figure 8: LKAS with TJA

4.4 State Diagram

This section will feature several state diagrams. These state diagrams will be used to describe changes between states within the system. States are blue boxes, and they describe the type of state that the system is in, such active or inactive. The arrows between states represent transitions between states in the diagrams. These are representative of functions or conditions that need to be met to reach a state.

Figure 9 below is the state diagrams that illustrates the sequences in Figure 5 above. This represents the relationship between the steering wheel activation and deactivation. The Activate and Deactivate functions are called from the driver pressing a physical button on the steering wheel.

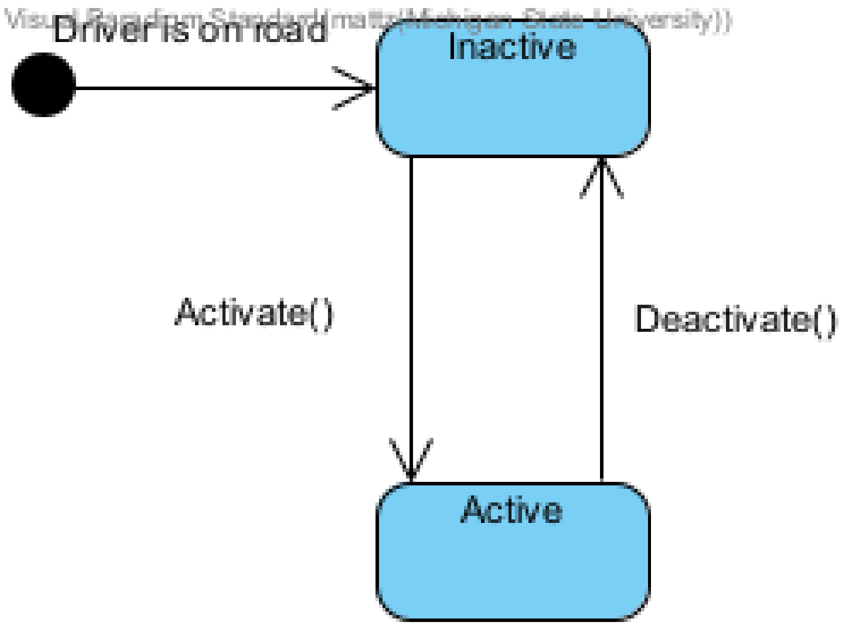

Figure 9: Activate and deactivate using driver input

In Figure 10 below, the state diagram illustrates the process in which the vehicle locks onto a target. Once the TJA system is active, it will continuously check for target objects. Even if a target object is detected, the vehicle, by calling the radar, will continuously check for target objects and report back if they are found. To provide accurate and safe driving, the system must constantly check for new targets, regardless of target detection.

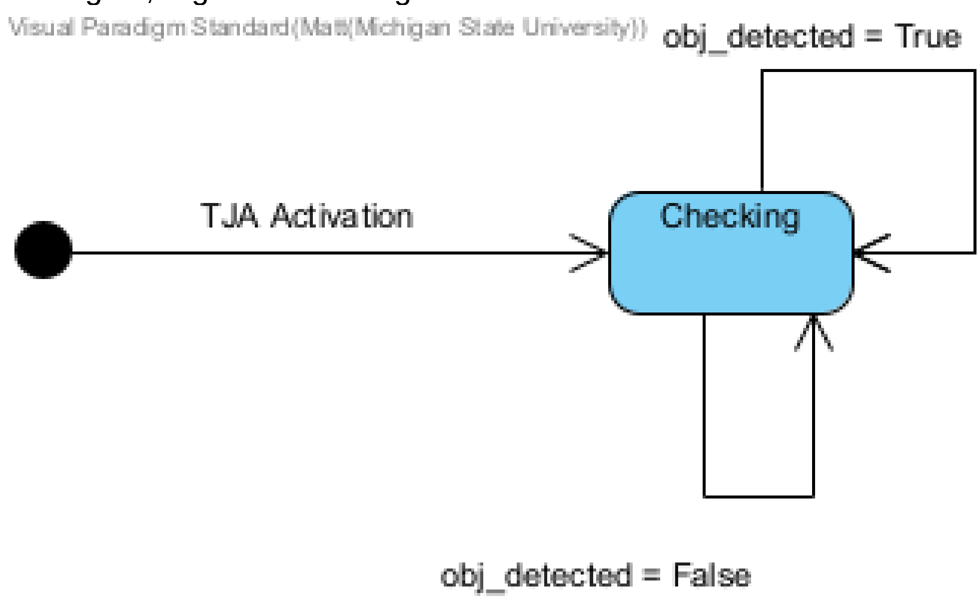

Figure 10: Target lock

In Figure 11 below, the state diagram details how an engaged TJA system interacts with the target vehicle. As the distance between the target vehicle changes, the TJA operates in a way to match the vehicle in front once it has successfully reached a safe maintenance distance. If the closing rate is positive, the system will reach a state of acceleration. Oppositely, the system will decelerate if the closing rate is less than zero until a closing rate of zero is achieved. At which point, it will maintain.

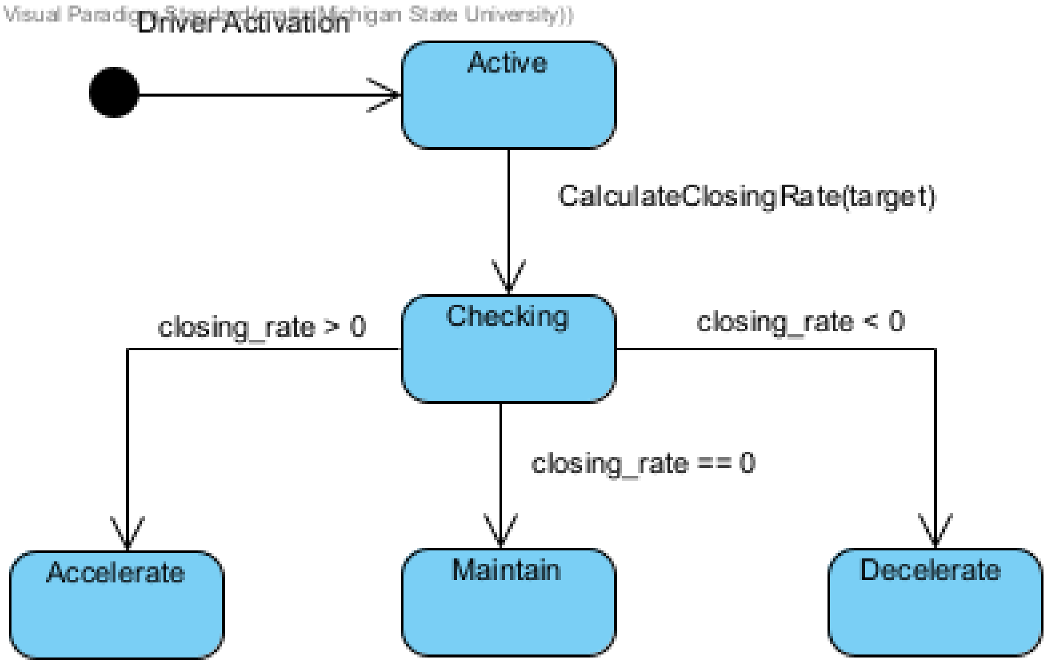

Figure 11: Maintain Distance

In Figure 12, the state diagram illustrates the relationship between the TJA system and lanes on the road. Once the TJA system becomes active, the camera on the vehicle will be activated as well. Once the camera is activated, the lanes will be consistently checked to determine if the vehicle is within the lanes. Regardless of the outcome, the camera will continue to check the lane. If the lane checking returns false, the vehicle will be notified and then it will be up to the vehicle to alert the driver via the steering wheel resistance.

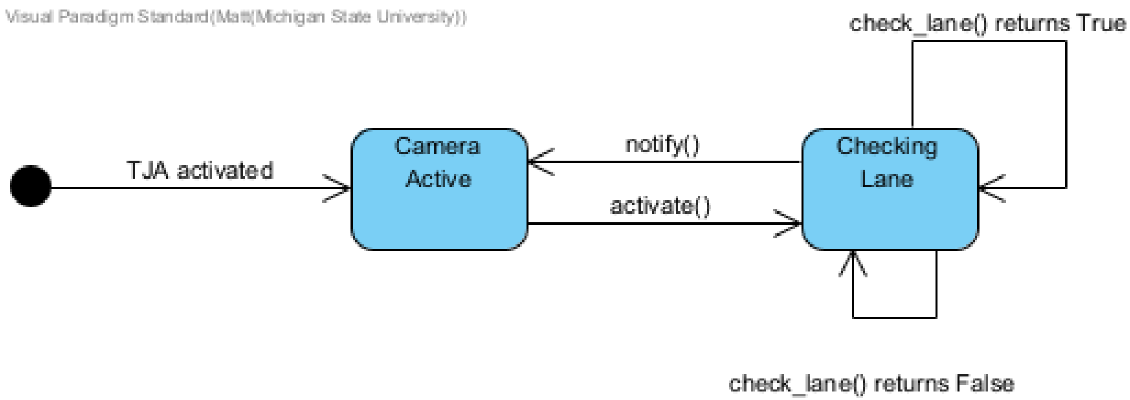

Figure 12: Lane Change

5 Prototype

The prototype shows how the TJA system is expected to operate on interstate roads. With the prototype, the user can control the environment in which the vehicle operates. They can change both the operating vehicle and target vehicle speeds, activate/deactivate the TJA system, the vehicle separation goal, and choose when a merging vehicle enters the lane.

When the simulation is started, the user can monitor how the TJA system works as it has a target and attempts to maintain a set distance between them.

5.1 How to Run Prototype

To run the prototype, navigate to our team website (linked here and at the top navigation bar labeled “Prototype”) and press both the “START SIMULATION” button and the “ACTIVATE TJA” button. This runs the prototype on the web browser. To study more precise cases, the user may input a starting distance and a distance goal that specifies how close the user wants the vehicle separation to be. The user may also control the speeds of the vehicles to see how TJA operates with different speeds.

It should work for all operating systems. There are no plugins, but there are libraries including bootstrap CSS.

5.2 Sample Scenarios

Scenario 1 - Activating the TJA system using the button will only operate when the vehicle is below 40 KPH and above 0 KPH. When it is on, the text for closing rate and vehicle speeds will be displayed as green, and when it is off, the texts will be red. In this state, the operating vehicle will gradually increase speed and slow down respectively to match the speed of the target vehicle, with the maximum achievable speed being 40 KPH.

The maximum speed is achieved at 40 KPH to close the gap between the two vehicles. Once the operating vehicle gets close enough to the distance goal range, which is set to the user's choice, in meters, then the operating vehicle will start decelerating. Notice in Figure 13 below, that once the operating vehicle approaches the target vehicle, the TJA will cause the operating vehicle to slow down to achieve a closing rate of zero.

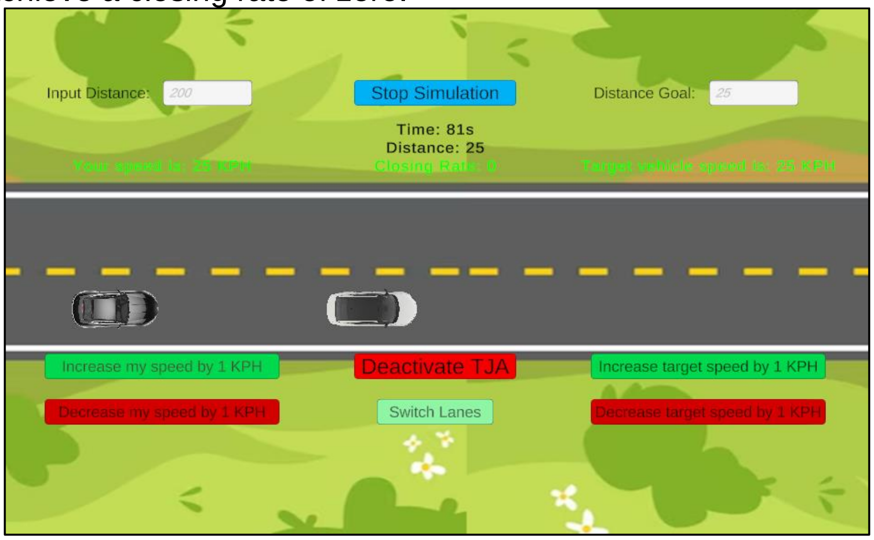

Figure 13: Match speed of target vehicle after TJA is activated

Scenario 2 - Manually decreasing the speed of the operating vehicle while TJA is on will be detected as a manual break and will deactivate TJA and run ACC.

In Figure 14 below, the user has pressed on the "Decrease my speed by 1 KPH" button which counts as a brake while the TJA was on, so the TJA has been switched off indicated by the red text of the speed of the vehicles and the closing rate. In this state, it runs ACC until TJA is reactivated by the user.

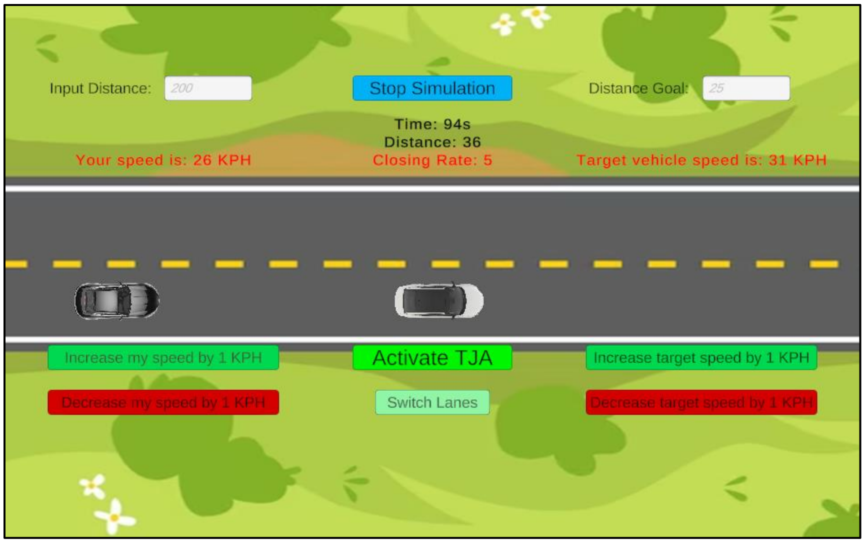

Figure 14: Braking turns off TJA

Scenario 3 - While TJA is on, the speed of the operating vehicle will increase or decrease to achieve a closing rate of zero when the target is within the range of the distance goal. And once the distance goal is reached, if the target vehicle accelerates or decelerates the operating vehicle will also accelerate and decelerate, respectively.

Observe in Figure 15 below that the closing rate of zero is achieved by the TJA system at the maximum achievable speed, which is 40 kilometers per hour.

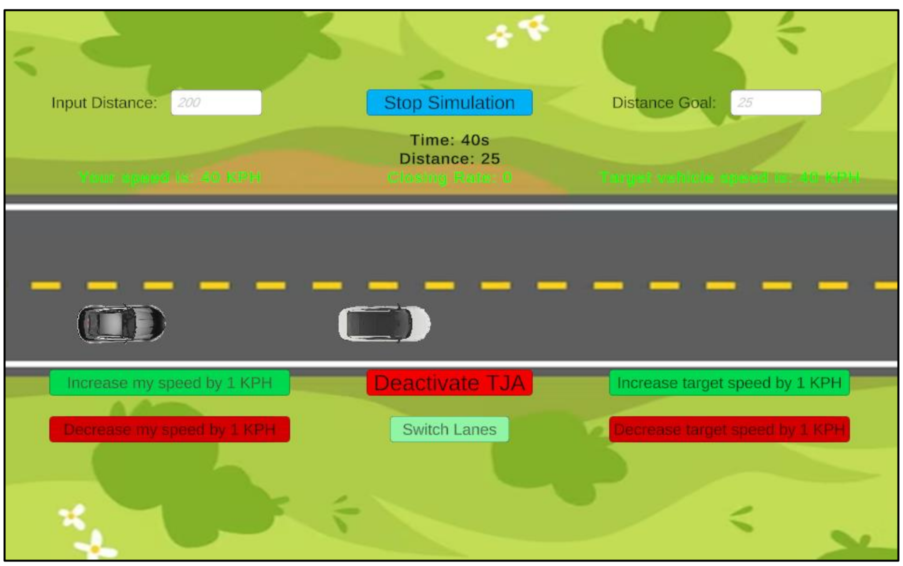

Figure 15: Maintain set distance goal with closing rate reaching zero while TJA is on at the maximum speed of 40 KPH

Scenario 4 – While the TJA system is activated, if the target vehicle comes to a complete stop, then the operating vehicle will also come to a complete stop after reaching its distance goal and maintains the closing rate of zero. If the target vehicle begins to accelerate, then the operating vehicle will accelerate as well to maintain the closing rate of zero.

In Figure 16 below, the prototype describes how the closing rate is zero while both cards have a speed of zero, indicating that they are completely stopped.

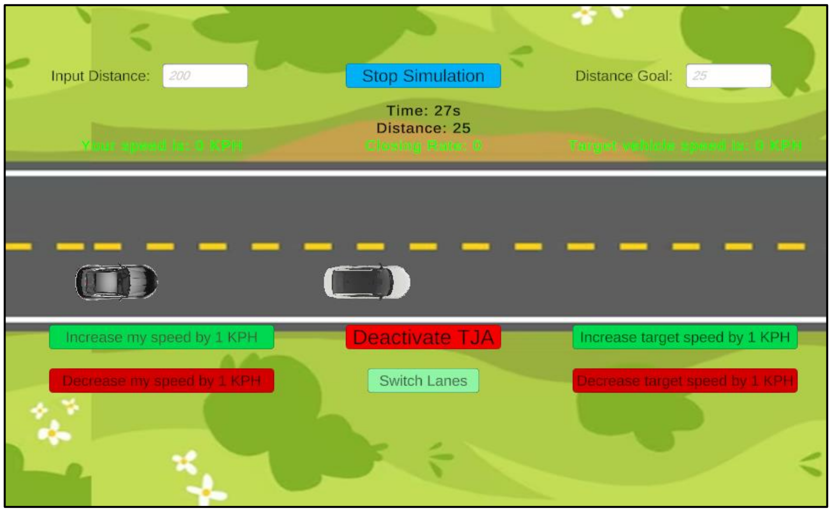

Figure 16: Target vehicle and operating vehicle at a complete stop

Scenario 5 – While the TJA system is activated, the driver has the ability to change lanes. When the driver changes lanes, the TJA system will scan for a new target vehicle. If a new target vehicle is not detected, the system will reengage standard cruise control and reset to the initial set speed until a target is detected again.

In Figure 17 below, the vehicle, after changing lanes resets to the initial set speed in the other lane.

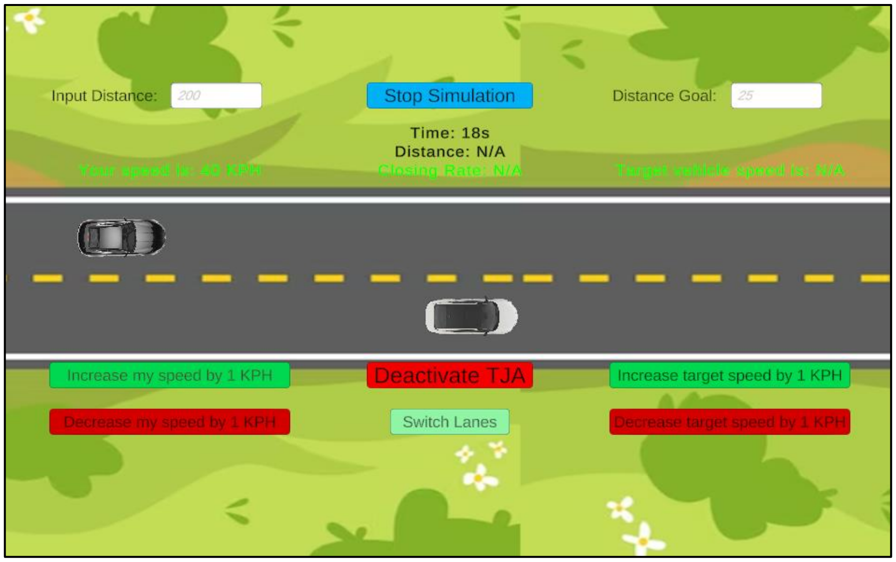

Figure 17: Changing lanes

6 References

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[1] J. C. Knight, "Safety critical systems: challenges and directions," Proceedings of the 24th International Conference on Software Engineering. ICSE 2002, Orlando, FL, USA, 2002, pp. 547-550.

[2] R. Le, B. Cooperkawa, M. Zaleski, A. Hoang, and E. Silver, "Traffic Jam Assist," Traffic Jam Assist Project, https://cse.msu.edu/~coope445/ (accessed Nov. 13, 2023).

[3] "Traffic Jam Assist Customer: Mr. William Milam, Wmilam Consulting LLC Motivation." Accessed: Nov. 13, 2023. [Online]. Available: https://www.cse.msu.edu/~cse435/Projects/F2023/ProjectDescriptions/2023-TJA-WMilamConsulting-Milam.pdf

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.