Software Requirements Specification (SRS)

Pedestrian Collision Avoidance System

Authors: **Eden Haase, Dean Eggenberger, Ashley Arciniega, Jacob Zawacki, Judy Effendi**

Customer: **Chris Capaldi**

Instructor: **Dr. Betty H. Cheng**

1 Introduction

The auto industry has had an intense interest in autonomous or highly automated driving, requiring a complex system that takes care of all aspects of driving. The Pedestrian Collision Avoidance System (PCAS) is meant to improve autonomous/highly automated driving by avoiding collisions with pedestrians. This system is used to determine the reaction of the autonomous vehicle when there is a pedestrian that will be in its path. The PCAS uses camera sensor inputs to determine if the vehicle needs to slow down, then uses the autonomous vehicle's brake by wire system to act accordingly.

This document details functionality, requirements, constraints, and dependencies of the PCAS. To make these details more explicit, models are included throughout. A prototype is also included to give a visual representation of how the PCAS will react to different scenarios.

1.1 Purpose

The purpose of this document is to outline the PCAS in a way that is easily understood by the customer, stakeholders, and developers. It gives an in-depth outline of the customers requirements and how the PCAS is designed with those requirements in mind. This will give the customer another opportunity to ensure that the PCAS is what they need. It will also give developers a thorough understanding of the PCAS before they begin implementing and designing it. This document is also intended for any stakeholders that would like to understand all aspects of the PCAS.

1.2 Scope

The Pedestrian Collision Avoidance System (PCAS) is an embedded system, and is designed to function within an automotive vehicle in order to prevent collisions with pedestrians while at steady state velocity. The PCAS uses camera and failsafe sensor output from the vehicle to carry out responses necessary to ensure that no pedestrian collisions occur.

Using the camera and failsafe sensor output, the PCAS will detect pedestrians in the path of the vehicle and will decelerate the vehicle as necessary while alerting the driver. The driver has the ability to override the PCAS's deceleration mechanism. There is no override for the alert mechanism.

In the case that the camera sensor is not able to obtain sufficient input, the vehicle will alert the driver that it must be cleaned. Until the camera sensor is cleaned, the PCAS will remain inactive. In the event of a pedestrian collision, legal liability will not be placed on the PCAS.

1.3 Definitions, acronyms, and abbreviations

- **Pedestrian Collision Avoidance System (PCAS):** The PCAS is the entire system explained throughout this document.
- **Alarm Warning System (AWS):** The AWS is the noise connected to the vehicle's sensors that transmits a sound when triggered.
- **Human Machine Interface (HMI):** The HMI is the physical control panel that communicates with the driver, typically to the right of the steering wheel.

1.4 Organization

The remainder of the document is organized as follows. First, section 2 describes the PCAS. Next, section 3 describes the system's specific requirements, including global invariants, system requirements, and cybersecurity requirements. Section 4 describes the modeling requirements, the use case diagram, domain model, and sequence diagram, along with detailed descriptions that model the system's operation. Lastly, section 5 demonstrates different scenarios the PCAS may encounter using a prototype.

2 Overall Description

This section will be focusing on describing the main functionalities and dependencies of the PCAS: the Product Perspective, Product Function, User Characteristics, Constraints, Assumptions and Dependencies, and Apportioning of Requirements.

2.1 Product Perspective

The Pedestrian Collision Avoidance System (PCAS) is responsible for the complete mitigation of pedestrian collisions of the vehicle at a steady state velocity. The implementation of a collision avoidance system at steady state velocity is in its infancy when considering the current deployment of vehicles, but new technologies such as pedestrian detection systems make systems like the proposed PCAS increasingly practical. The injury, damage, and loss of life that comes from pedestrian collisions among the current population present a large area of concern, and effort to create such a system to prevent such incidents is vital. Eliminating pedestrian collisions at steady state speed within the vehicle in which PCAS operates while causing minimal obstruction to traffic is the high level goal of the PCAS.

The PCAS is an embedded subsystem of the vehicle in which it operates, it relies on a number of components of the vehicle, such as the camera sensors. The PCAS cannot function properly on its own. It interacts with the brake-by-wire system within the vehicle in order to decelerate when necessary to prevent collision with a pedestrian. In addition, the PCAS alerts the driver of a pedestrian within its path through initiating a beeping sound and by vibrating the driver's seat through the vehicle's alarm warning system.

2.2 Product Functions

The PCAS will be paired with an autonomous or highly automated vehicle to handle a fundamental aspect of driving, avoiding collisions with pedestrians at all times. This makes the main objective of the PCAS to eliminate pedestrian collisions between the autonomous vehicle and a pedestrian in its path when the vehicle is moving forward. The PCAS communicates with two external actors: a stereo camera and the brake by wire system. The PCAS will take information from the stereo camera and determine if the vehicle needs to slow down or stop. If the vehicle needs to slow down the PCAS will communicate that to the brake by wire system. This relationship is shown in Figure 1 below. The stereo camera will be positioned on the front of the autonomous vehicle in a location that gives a view that encompasses 180 degrees of the autonomous vehicle's path. This stereo camera will be able to recognize and track pedestrians giving the pedestrians location relative to the vehicle with an accuracy of +/- 0.5 meters. The stereo camera will be able to detect the pedestrian's speed and direction with a +/- 2 meters per second and +/- 5 degrees respectively. The stereo camera will communicate with the PCAS giving it a packet of information holding pedestrian recognition and tracking, the pedestrian's location (x,y) relative to vehicle, and the pedestrian's velocity (speed & direction). The brake-by-wire system will reduce the velocity of the autonomous vehicle as directed to by the PCAS.

The PCAS will be activated when the autonomous vehicle is shifted into drive. Once activated, the PCAS will continuously monitor the packets of information it receives from the stereo camera every 100 milliseconds. With this information, the PCAS will determine if the vehicle needs to brake by calculating the time it will take for a collision to take place between the autonomous vehicle and the pedestrian. It will determine the deceleration needed to ensure the autonomous vehicle does not exceed 16 kilometers per hour when it is within 4.5 meters of the pedestrian. It will also calculate the deceleration needed to bring the autonomous vehicle to a stop 1.5 meters before the autonomous vehicle would collide with the pedestrian. The PCAS will send these values to the brake by wire system which will reduce the velocity of the autonomous vehicle as requested. Once the PCAS determines it needs to slow down it should alert the user by making a beeping sound and vibrating the seat. Both of these are already functions of the autonomous vehicle so the PCAS just communicates to the autonomous vehicles alarm warning system that these things need to happen. If the driver wants to override the system they will need to press the brake and take control of the speed of the autonomous vehicle by manually pressing the gas pedal. Once the pedestrian is no longer in the path of the autonomous vehicle the PCAS will notify the brake-by-wire system that it no longer needs to slow down or stop the autonomous vehicle allowing it to accelerate to its intended velocity. Once the vehicle is shifted out of the drive state the PCAS will turn off.

System Architecture:

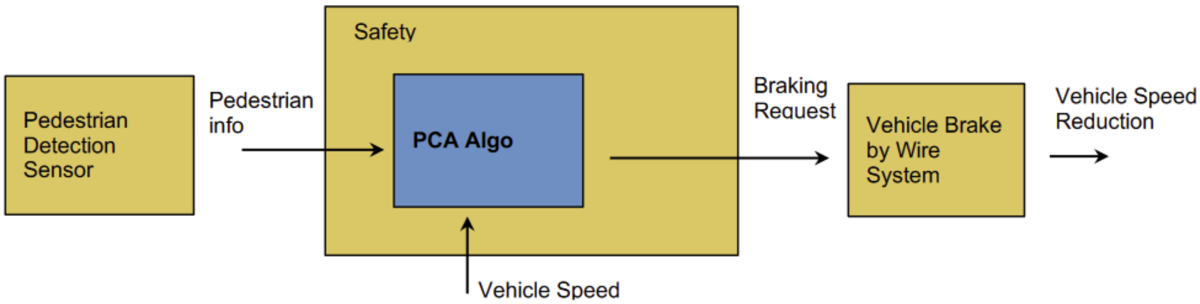


Figure 1: System Architecture

This figure shows how the PCAS interacts with connected systems. The PCAS takes in pedestrian info and vehicle speed, determining if the vehicle needs to brake. If the PCAS determines braking is necessary, then a braking request is sent to the Brake by Wire System, which slows the vehicle down.

2.3 User Characteristics

The user of the system should be a legally licensed driver. The user must obey all traffic safety laws and maintain reasonable driving speed. The user should be able to react to alerts given by the system and respond accordingly. Lastly, in the event of a critical system error, the driver should be able to take control of the vehicle manually.

2.4 Constraints

There are several constraints applied to the PCAS in order to ensure maximum safety and reliability. The system must have a working radar and camera system. It may be possible for the system to function if one of these systems is not working properly, but in the event that both systems are not working, control must be returned to the user. The camera and radar are used in determining whether the system is at risk of colliding with an external object. Any failure in these systems puts the user at risk, compromising safety. Another safety critical property is to have a working brake-by-wire system, failures in the system put immense risk on the system's ability to properly function. As a result, the system will not activate if a problem occurs, once again returning full control to the user. Another constraint includes signal timing. Since the

PCAS is constantly receiving information and running calculations, it is important that the system both sends and receives this information in a near instantaneous timeframe. Any delays in the system cause potential danger to the user and thus must be mitigated.

2.5 Assumptions and Dependencies

Our system will have 5 assumptions. Assumption 1: The PCAS will not activate if weather conditions are not ideal. Assumption 2: Hardware systems, such as the pedestrian detection sensors and brake-by-wire system are installed and operational. Assumption 3: The vehicle is capable of accelerating and braking. Assumption 4: System only operates when hardware systems are functioning properly. Assumption 5: User isn't actively fighting the system's operation (trying to speed up while the system tries to slow down).

2.6 Apportioning of Requirements

Several components of the PCAS are not considered in this document and may be addressed in the future. First, our system does not account for how the stereo camera collects and sends the information to the PCAS. This is abstracted and we can assume that it works and sends the required information. The data stream provided by the stereo camera will not be fully detailed in this project. The algorithm used to determine the deceleration needed to slow down the vehicle is not outlined in this document and can be discussed in the future. The way the brake by wire system slows down the vehicle will not be included in this project and is considered abstracted.

3 Specific Requirements

Section three describes the global invariants, system requirements, and cyber security requirements for the PCAS to be developed.

3.1 System Requirements

1. The autonomous vehicle will have the following properties:
    1.1. The autonomous vehicle shall have a normal steady state speed of 50 kph.
    1.2. The autonomous vehicle shall have an acceleration to steady state speed of 0.25g (1g = 9.81 m/s^2).
    1.3. The autonomous vehicle's width is 2m.
2. The PCAS will be able to avoid collisions with pedestrians that have the following characteristics:
    2.1. The pedestrian can be stationary or in motion. While the pedestrian is in the static state they will have a speed of 0 kph. While the pedestrian is in motion they will have a speed of 6kph.
    2.2. The pedestrian can change velocity with infinite acceleration.
    2.3. The size of the pedestrian in the x-y plane shall be considered a circle with a 0.5 m diameter.
    2.4. When the pedestrian is in motion they shall only move perpendicular to the vehicle's path.
3. When the autonomous vehicle is put into drive the PCAS shall activate within 0.25 seconds.
4. The PCAS shall communicate with a stereo camera positioned on the front of the autonomous vehicle.
    4.1. The stereo camera shall have a view that encompasses the front 180 degrees of the autonomous vehicle.
    4.2. The stereo camera shall be able to recognize and track pedestrians giving the pedestrians location relative to the vehicle with an accuracy of +/- .5m
    4.3. The stereo camera shall be able to detect the pedestrian's speed and direction with a +/- 2m/s and +/- 5 degrees respectively.
5. When the autonomous vehicle is in drive a stereo camera shall send the PCAS a packet of information every 100ms (the cycle time of the stereo camera).
    5.1. The packet of information given to the PCAS by the stereo camera shall include: pedestrian recognition and tracking, Pedestrian location (x,y) relative to vehicle with accuracy +/- .5 m, Pedestrian velocity (speed & direction). Speed +/- .2 m/s. Direction +/- 5 deg
6. After the pedestrian has been detected by the stereo camera the PCAS shall determine when the vehicle needs to brake using the stereo camera outputs.

6.1. The PCAS shall determine if the vehicle needs to brake by calculating the time it will take for a collision to take place with the vehicle and the pedestrian.The PCAS shall ensure that the vehicle decelerates such that the autonomous vehicle does not exceed 16kph within 4.5m of the pedestrian. The PCAS shall also calculate the deceleration needed to bring the vehicle to a stop 1.5m before the vehicle would collide with the pedestrian.

6.2. The PCAS will send a signal with the declaration speed to the Vehicle Brake by Wire System which will then reduce the velocity of the autonomous vehicle as requested. The Brake by Wire system shall:

   6.2.1. respond to requests from our system.
   6.2.2. override the steady state velocity of autonomous vehicle when commanded to brake.
   6.2.3. apply brake torque using electro-mechanical actuators on all four wheels of the autonomous vehicle.
   6.2.4. have a deceleration accuracy within +/- 2%.
   6.2.5. have a response time to decelerate within 200ms.
   6.2.6. have a release time within 100ms.
   6.2.7. have a maximum deceleration is 0.7g.
   6.2.8. allow the autonomous vehicle to return to steady state velocity after the brake command ends.

7. When the autonomous vehicle begins to brake due to the Vehicle Brake by Wire System the PCAS shall continue to recalculate and evaluate the output from the stereo camera. This will account for the conditions of the road. If the autonomous vehicle is not stopping as expected from the first calculations it will continue to recalculate based on the new conditions every 100ms.
8. When the autonomous vehicle begins to brake due to the Vehicle Brake by Wire System the PCAS shall communicate with the vehicle's alarm warning system and alert the driver within 0.01 seconds of the autonomous vehicle braking. The alert will consist of a beeping sound and a vibration of the driver’s seat.
9. The PCAS shall allow the Driver to override the system after the autonomous vehicle is fully stopped. When the autonomous vehicle is completely stopped the driver may gain control by pressing the brake pedal. When this happens the PCAS will alert the driver using the alarm warning system to play a voice recording that says “The PCAS has been turned off” within .01 seconds of the brake pedal being pressed. The PCAS will no longer be liable for any collisions.
10. After the vehicle comes to a complete stop the system shall keep the vehicle in a complete stop until the pedestrian is no longer in the path of the autonomous vehicle.
11. Once the pedestrian is no longer in the path of the autonomous vehicle the PCAS shall no longer notify the Vehicle Brake by Wire System to stop the vehicle and allow the

vehicle to accelerate at a steady rate of 0.25g until the autonomous vehicle reaches its steady state speed of 50kph. This shall happen within 5s of the pedestrian no longer being in the path of the autonomous vehicle.

12. The system shall monitor every 5 minutes to see if the stereo camera is obstructed.
    12.1. If the stereo camera is obstructed the system will alert that user that it needs to be cleaned and that the system shall not be activated until the camera is cleaned off. When the system is not activated we will not be legally responsible for any collisions.
13. When the vehicle is no longer in drive the system shall turn off within 0.25 seconds.
14. If there is a problem with the main system (software failure, malicious attack), the PCAS will switch to the failsafe system.
    14.1. The failsafe system has a slower response time than the normal system (200ms to 900ms) and will need to be considered.
    14.2. The driver will be notified that the failsafe system is activated via an audible beep.

3.2 Global Invariants

1. The PCAS meets performance requirements despite weather, lighting, and poor road conditions.
2. The PCAS must always avoid collisions with pedestrians while active.
3. The vehicle shall not exceed 16 kph if an obstacle is detected within 4.5m
4. The autonomous vehicle must slow down to avoid hitting pedestrians, speeding back up to the autonomous vehicle's steady state speed once risk is gone.
5. The PCAS must minimize lost time
    5.1. "Time difference (in seconds) between system on and system off to reach a common point beyond the pedestrian with controlled vehicle back again at steady state velocity"

3.3 Cyber Security Requirements

1. The packets of information the PCAS receives should be encrypted to reduce the risk of tampering by outside forces
    1.1. Encryption is different on a system-by-system basis to avoid the risk of a whole fleet going down if one vehicle is compromised
2. Any outward communication from the PCAS should be limited when possible and heavily encrypted
3. Isolate PCAS from as many of the other vehicle systems as possible
    3.1. Only interact with the systems that are **absolutely necessary** (brake by wire,

pedestrian detection sensors and cameras, etc.)

4. The system should do its best to prevent any sort of malicious cyber attack, but in the event that a security breach is detected, alert the driver and shut off PCAS.

4 Modeling Requirements

This section presents various diagrams and their corresponding descriptions to depict key elements, interactions, scenarios, and services of the PCAS in detail. It will include Use Case Diagrams, Object Oriented Models, Sequence Diagrams, and State Diagrams. All of these diagrams will be presented using unified modeling language notation.

4.1 Use Case Diagram and Descriptions

The following sections introduce the use case diagram for the PCAS and the corresponding use case descriptions. A use case diagram captures a user's visible function and interaction with the system. The use case diagram describes each use case in detail.

4.1.1 Use Case Diagram

Figure 2 shown below gives a general description of the major use cases involved with the PCAS. The rectangle outlined in black represents the PCAS boundary. Anything inside this boundary is included in the PCAS and everything on the outside is an actor that interacts with the PCAS. The sick figures represent actors that will interact with our system. These actors include the driver, brake by wire system, stereo camera, pedestrian, failsafe system, and alarm warning system. Each actor interacts with the PCAS allowing the PCAS to perform a function. These functions are represented with ovals outlined in black and are placed within the system boundary. The interactions are represented using different lines to connect the actor to the function. Associations are represented by a solid black line. Associations are just connections between two things showing that they will interact with each other. Includes are represented using dotted arrows. This shows that the function being pointed to is included in the activity of the other function the arrow is coming from.

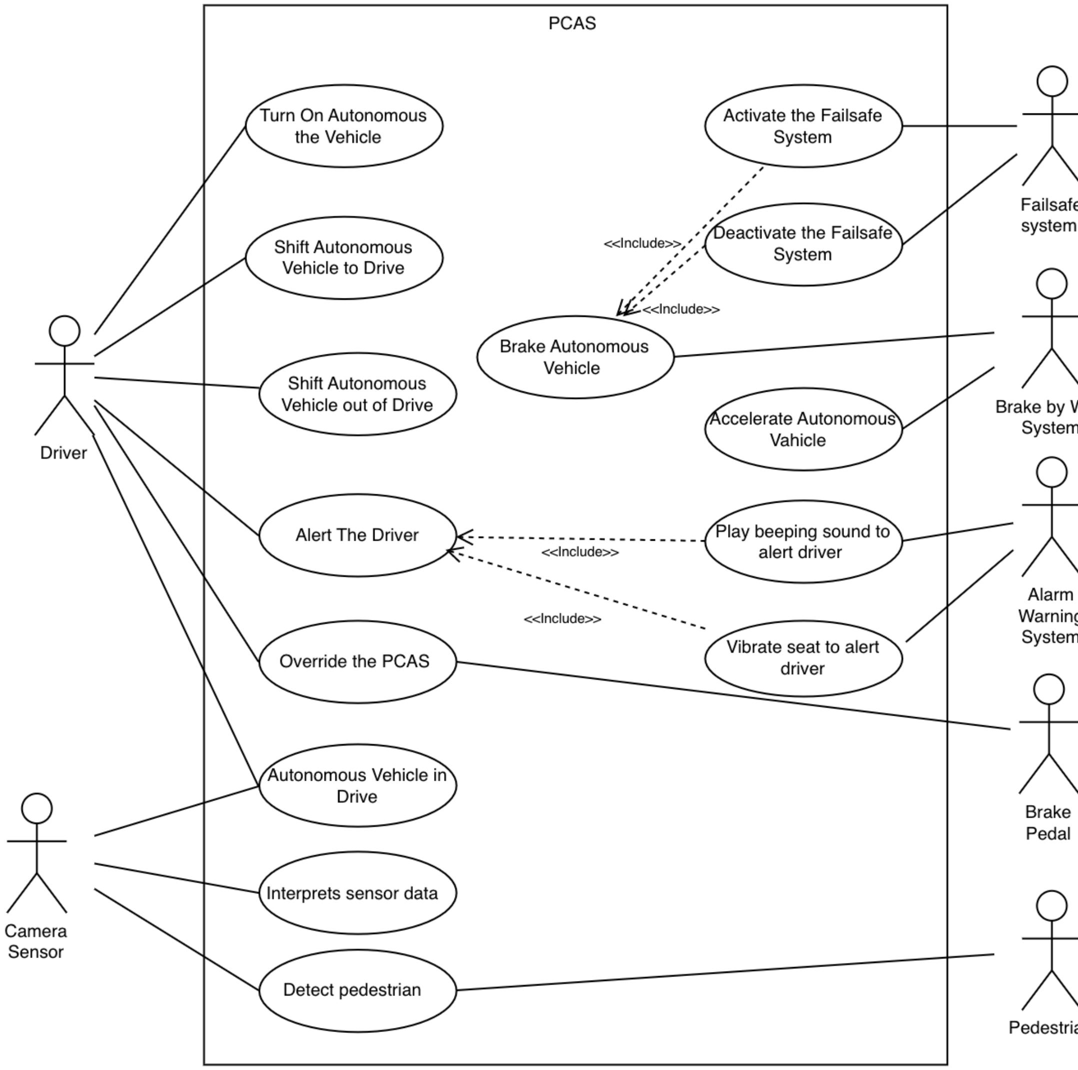


Figure 2: Use Case diagram for PCAS

4.1.1 Use Case Descriptions

Tables 1 through Table 14 detail the individual use cases depicted in Figure 2. The tables will provide a comprehensive description for each individual use case. The Use Case in the table will give a title for that use case. The Description will give a brief overview for that specific use case. The Type will categorize the use case to either primary or secondary. The Includes and Extends will indicate whether or not other use cases are related to this one. The Cross-refs will list the requirements from Section 3 that are included in this use case. The Use cases will describe other use cases that must be satisfied for the current use case to be active.

Use Case:	Turn on the Autonomous Vehicle
Actors:	Driver
Description:	When the autonomous vehicle is turned on the PCAS should not be turned on as the autonomous vehicle has not been shifted into drive.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	1
Use cases:	N/A

Table 1: Use case description for *Turn on Autonomous Vehicle*

Use Case:	Shift Autonomous Vehicle to Drive
Actors:	Driver, Brake By wire System, Stereo Camera
Description:	When the autonomous vehicle is shifted to drive mode, the PCAS shall activate within .25 seconds. The brake by wire system and stereo camera will also be activated. It shall immediately begin analyzing the packets of information coming from the stereo camera.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	1, 3

Use cases:	Turn on the car

Table 2: Use case description for *Shift Autonomous Vehicle to Drive*

Use Case:	Autonomous Vehicle in Drive
Actors:	Stereo Camera
Description:	When the autonomous vehicle is in drive the stereo camera should be communicating with the PCAS sending packets of information every 100 milliseconds.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	4, 5
Use cases:	Turn on the Autonomous Vehicle, Shift Autonomous Vehicle to Drive

Table 3: Use case description for *Autonomous Vehicle in Drive*

Use Case:	Interpret Sensor Data
Actors:	Stereo Camera
Description:	The PCAS continuously analyzes packets of information from the stereo camera to determine if the autonomous vehicle needs to slow down. The PCAS will also continuously monitor the stereo camera feed every 5 minutes to determine if it is obstructed.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	2, 4, 5, 12
Use cases:	Turn on the Autonomous Vehicle, Shift Autonomous Vehicle to Drive,

	Autonomous Vehicle in Drive

Table 4: Use case description for *Interpret Sensor Data*

Use Case:	Detect Pedestrian
Actors:	Stereo Camera
Description:	The stereo camera detects a pedestrian in the path of the autonomous vehicle. When it detects a pedestrian the PCAS must perform calculations to determine if there will be a collision.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	2, 6
Use cases:	Turn on the Autonomous Vehicle, Shift Autonomous Vehicle to Drive, Autonomous Vehicle in Drive

Table 5: Use case description for *Detect Pedestrian*

Use Case:	Brake Autonomous Vehicle
Actors:	Brake by Wire System
Description:	When the PCAS determines it needs to brake it will tell the brake by wire to slow down the autonomous vehicle. It will come to a stop and stay stopped until the pedestrian is no longer in the path of the autonomous vehicle.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	1, 6, 7, 10

Use cases:	N/A

Table 6: Use case description for *Brake Autonomous Vehicle*

Use Case:	Accelerate Autonomous Vehicle
Actors:	Brake by Wire System
Description:	Once the pedestrian is no longer in the path of the autonomous vehicle the PCAS shall no longer notify the Vehicle Brake by Wire System to stop the autonomous vehicle and allow the vehicle to accelerate at a steady rate of 0.25g until the autonomous vehicle reaches its steady state speed of 50kph. This shall happen within 5s of the pedestrian no longer being in the path of the autonomous vehicle.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	11
Use cases:	N/A

Table 7: Use case description for *Accelerate Autonomous Vehicle*

Use Case:	Play beeping sound to alert driver
Actors:	Alarm Warning System
Description:	When the PCAS determines it needs to brake the autonomous vehicle it will also send a message to the alarm warning system to play a beeping sound within .01 seconds of the brakes being activated.
Type:	Primary
Includes:	Alert the Driver
Extends:	N/A

Cross-refs:	8
Use cases:	Brake Autonomous Vehicle

Table 8: Use case description for *Play beeping sound to alert driver*

Use Case:	Vibrate seat to alert driver
Actors:	Alarm Warning System
Description:	When the PCAS determines it needs to brake the autonomous vehicle it will also send a message to the alarm warning system to vibrate the driver's seat within .01 seconds of the brakes being activated.
Type:	Primary
Includes:	Alert the Driver
Extends:	N/A
Cross-refs:	8
Use cases:	Brake Autonomous Vehicle

Table 9: Use case description for *Vibrate seat to alert driver*

Use Case:	Alert The Driver
Actors:	Driver, Alarm Warning System
Description:	When the autonomous vehicle begins to slow down due to a pedestrian alert the user using two different sensory inputs.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	8
Use cases:	Brake Autonomous Vehicle

Table 10: Use case description for *Alert The Driver*

Use Case:	Override the PCAS
Actors:	Driver
Description:	To override the PCAS the driver must wait until the autonomous vehicle comes to a complete stop. Once it has come to a complete stop the driver must press the brake. When this happens the PCAS will alert the driver using the alarm warning system to play a voice recording that says “The PCAS has been turned off”. The PCAS will no longer be liable for any collisions.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	9
Use cases:	Brake Autonomous Vehicle

Table 11: Use case description for *Override the PCAS*

Use Case:	Activate the Failsafe System
Actors:	Failsafe System
Description:	If there is a problem with the main system (software failure, malicious attack), the PCAS will switch to the failsafe system. This system has a slower response time by 200ms to 900ms. The driver will be notified that the failsafe system is activated with an audio beep from the alarm warning system.
Type:	Primary
Includes:	Brake Autonomous Vehicle
Extends:	N/A

Cross-refs:	14
Use cases:	N/A

Table 12: Use case description for *Activate the Failsafe System*

Use Case:	Deactivate the Failsafe System
Actors:	Failsafe System
Description:	Once the problem with the main system is resolved the failsafe system will deactivate within 5 seconds.
Type:	Primary
Includes:	Brake Autonomous Vehicle
Extends:	N/A
Cross-refs:	14
Use cases:	Activate the Failsafe System

Table 13: Use case description for *Deactivate the Failsafe System*

Use Case:	Shift Autonomous Vehicle out of Drive
Actors:	Driver
Description:	When the vehicle is shifted out of drive the PCAS shall turn off within 0.25 seconds.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	13

Use cases:	N/A

Table 14: Use case description for *Vehicle Shifted out of Drive*

4.2 Domain Model

Figure 3 shown below is a domain model that shows elements of the PCAS and how they interact with each other. Each box outline in black is a class that is an individual object in the system. Lines connecting classes together describe the relationship between the two classes. A line without any symbols associated with it is an association. As association defines a conceptual connection between the two classes. An arrow connecting two classes represents a direct association meaning that the class being pointed to is contained in the class at the tail of the arrow. A diamond with multiple relationships connected to it is a ternary association and represents an association between all classes connected to it.

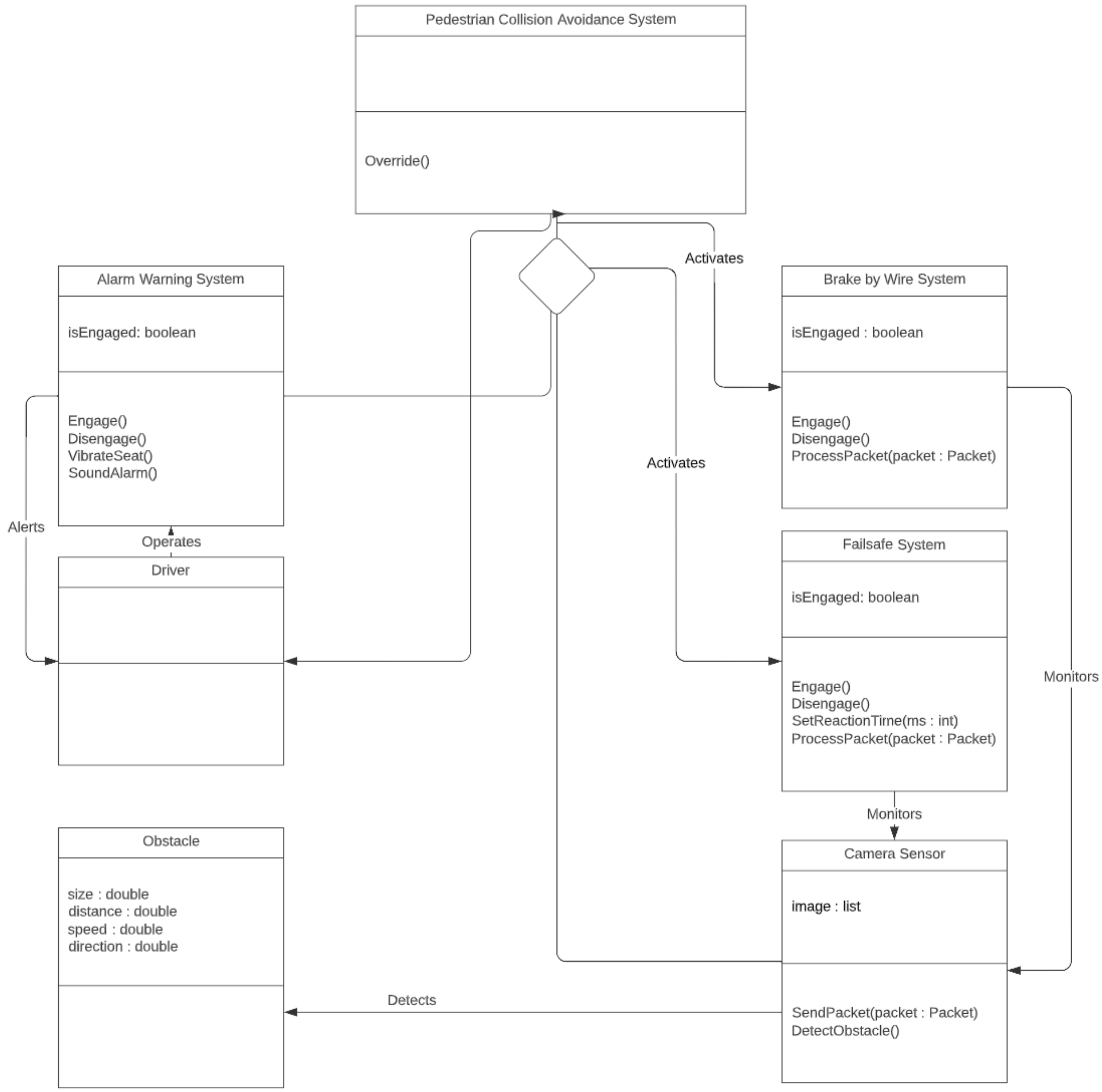


Figure 3: Domain Model for PCAS

4.3 Sequence Diagrams

In this section we will be showing our sequence diagrams. The purpose of these diagrams is to display how our systems classes and objects behave in different scenarios.

4.3.1 Static Pedestrian

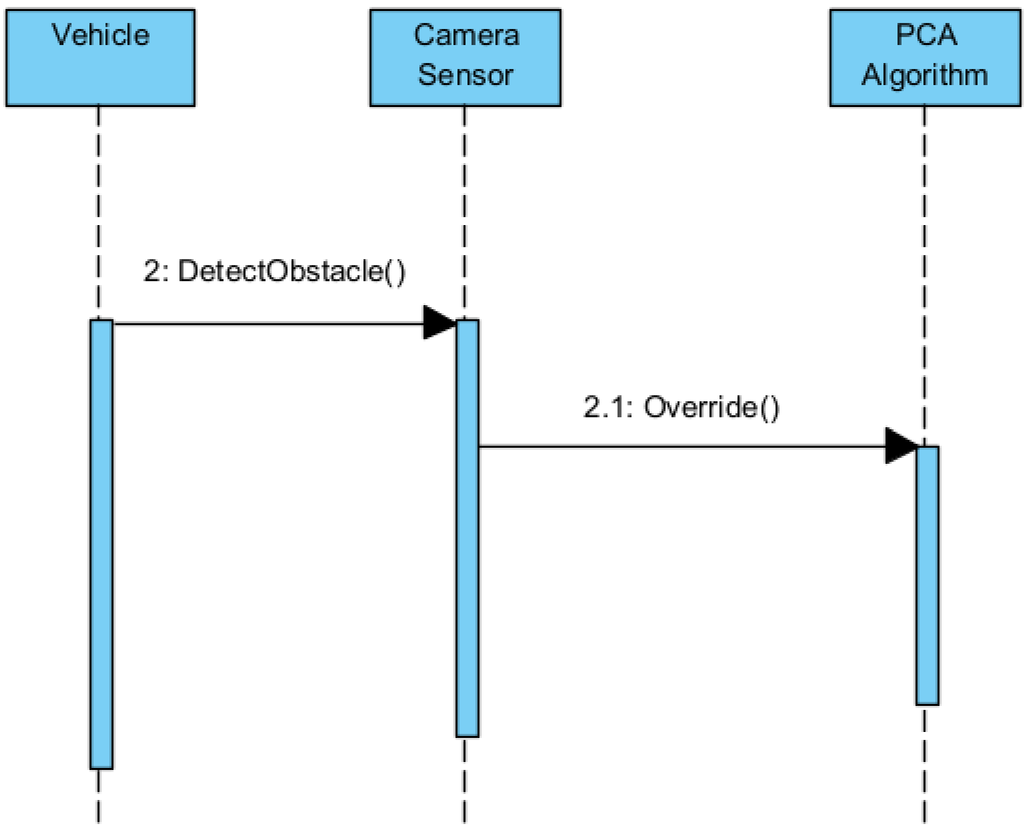


Figure 4: Static Pedestrian Sequence Diagram

Figure 4: This sequence diagram represents a scenario where the pedestrian is static. The pedestrian is detected by the camera sensor which is received by the PCA algorithm. The system overrides since nothing happens when a pedestrian is static.

4.3.2 Static Then Moving Pedestrian

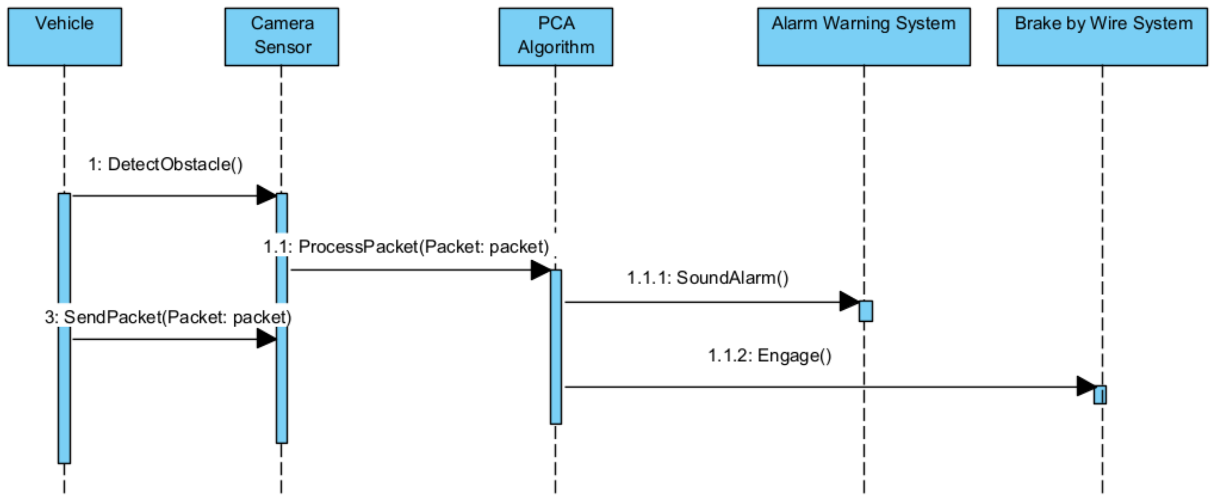


Figure 5: Static Then Moving Pedestrian Sequence Diagram

Figure 5: This sequence diagram represents a scenario where the pedestrian is static then moving. From the camera sensors, the obstacle is detected and packets are sent to the sensor which are processed and received from the PCA algorithm. The system sounds the alarm warning system and the brake by wire system is engaged since the pedestrian is detected and moving.

4.3.3 Moving Then Stopped Pedestrian

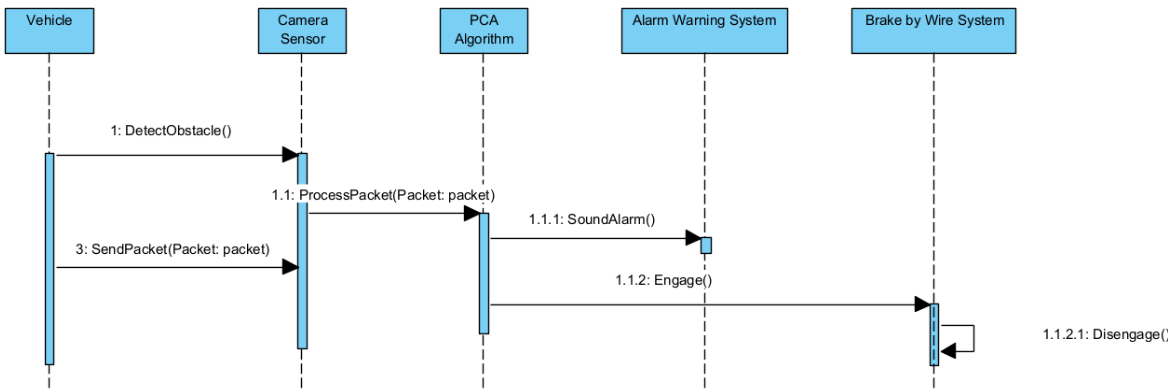


Figure 6: Moving Then Stopped Pedestrian

Figure 6: This sequence diagram represents when a pedestrian is moving then stopped. From the camera sensors, the obstacle is detected and packets are sent to the sensor which are processed and received from the PCA algorithm. The system sounds the alarm warning system and engages the brake by wire system but disengages when the pedestrian has stopped.

5 Prototype

An interactive prototype has been created to convey what the PCAS will do in different scenarios. There are a total of ten different scenarios that will express different interactions between the autonomous vehicle and a pedestrian. This prototype will visually represent how the PCAS will respond to each scenario. After interacting with this prototype the viewer should have a strong idea of how the PCAS will react to all ten scenarios.

5.1 How to Run Prototype

The prototype of the PCAS can be accessed using the following weblink: https://pcas-prototype.netlify.app/. This prototype was created using unity and is hosted on netlify. It has been embedded on the webql using simmer.io. It will be later hosted on the CSE server. The prototype should be easily accessible on any internet server. When the link is clicked it should take you to a “Home” screen pictured in Figure 6 below. This screen contains information about the prototype and has a button on the right to click for the three different cases given by the customer. From this home screen the user can click any of the three cases on the right and will be taken to the respective screens. The Case one screen is pictured in Figure 7 below, case two is pictured in Figure 8 below, and case three is pictured in Figure 9 below. These screens have their respective scenarios represented on the left of the screen by buttons. The user will click the button representing the scenario they would like to see and a video will play giving a visual representation of how the PCAS will handle each condition.

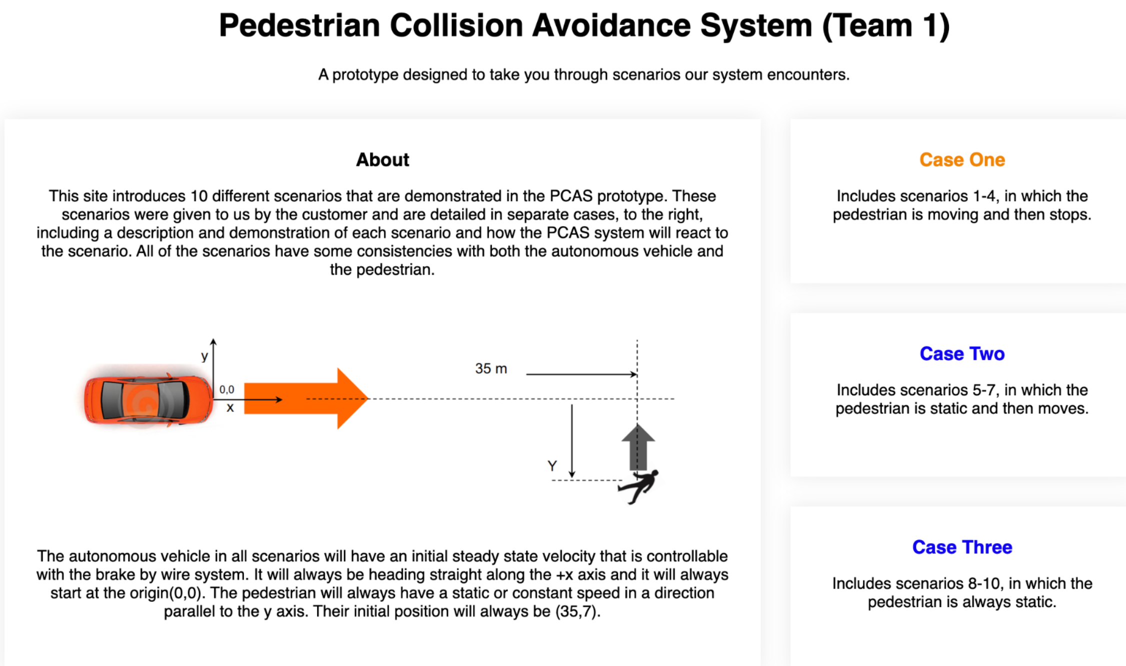
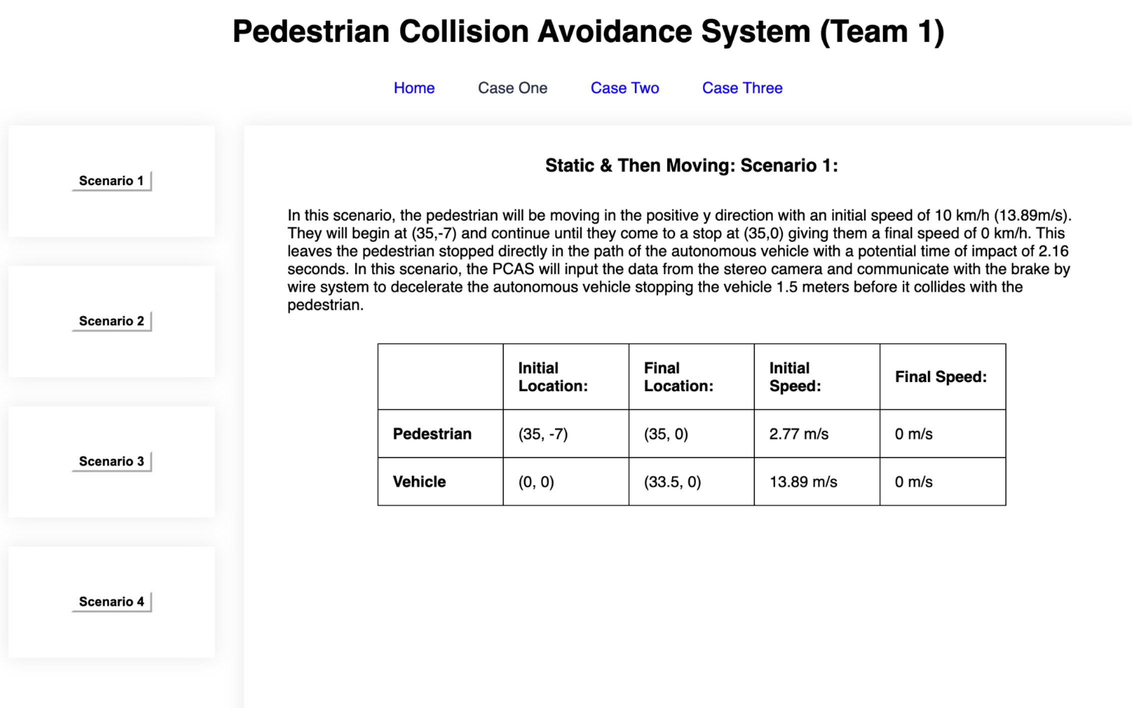


Figure 6: PCAS Prototype Home Screen



Pedestrian Collision Avoidance System (Team 1)

Home Case One Case Two Case Three

Scenario 1

Scenario 2

Scenario 3

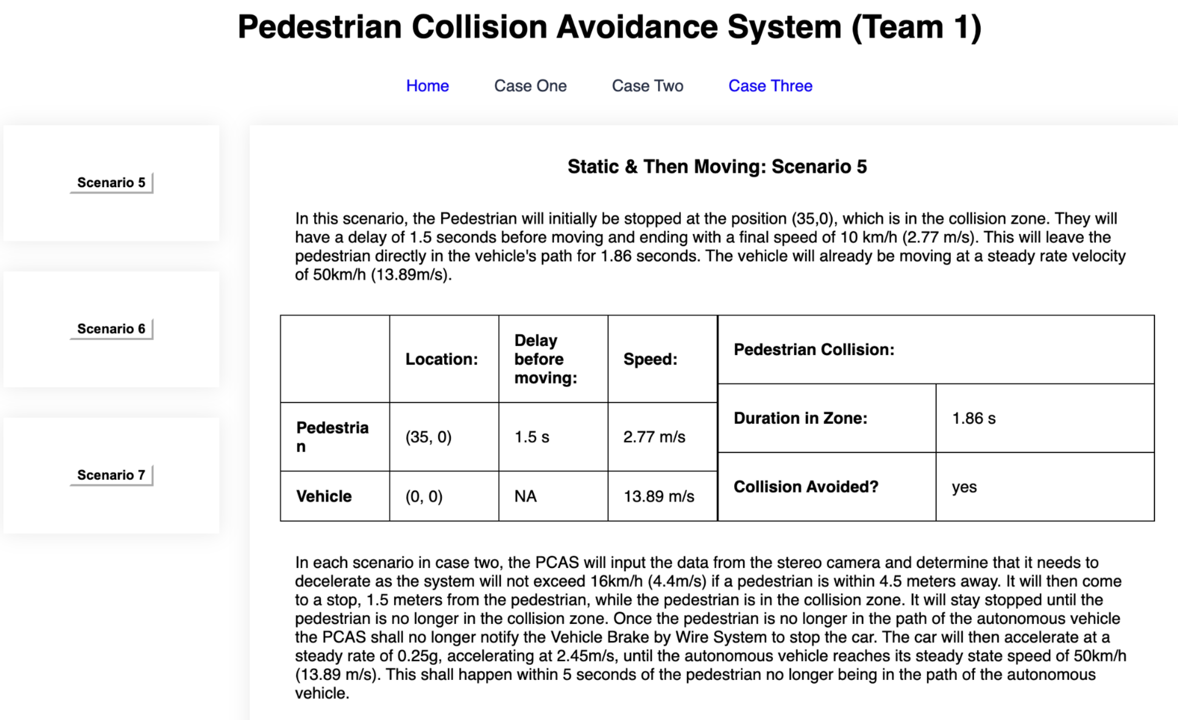
Scenario 4

Static & Then Moving: Scenario 1:

In this scenario, the pedestrian will be moving in the positive y direction with an initial speed of 10 km/h (13.89m/s). They will begin at (35,-7) and continue until they come to a stop at (35,0) giving them a final speed of 0 km/h. This leaves the pedestrian stopped directly in the path of the autonomous vehicle with a potential time of impact of 2.16 seconds. In this scenario, the PCAS will input the data from the stereo camera and communicate with the brake by wire system to decelerate the autonomous vehicle stopping the vehicle 1.5 meters before it collides with the pedestrian.

	Initial Location:	Final Location:	Initial Speed:	Final Speed:
Pedestrian	(35, -7)	(35, 0)	2.77 m/s	0 m/s
Vehicle	(0, 0)	(33.5, 0)	13.89 m/s	0 m/s

Figure 7: PCAS Prototype Case One Screen



Pedestrian Collision Avoidance System (Team 1)

Home Case One Case Two Case Three

Scenario 5

Scenario 6

Scenario 7

Static & Then Moving: Scenario 5

In this scenario, the Pedestrian will initially be stopped at the position (35,0), which is in the collision zone. They will have a delay of 1.5 seconds before moving and ending with a final speed of 10 km/h (2.77 m/s). This will leave the pedestrian directly in the vehicle's path for 1.86 seconds. The vehicle will already be moving at a steady rate velocity of 50km/h (13.89m/s).

	Location:	**Delay before moving:**	**Speed:**
Pedestrian	(35, 0)	1.5 s	2.77 m/s
Vehicle	(0, 0)	NA	13.89 m/s

Pedestrian Collision:	
Duration in Zone:	1.86 s
Collision Avoided?	yes

In each scenario in case two, the PCAS will input the data from the stereo camera and determine that it needs to decelerate as the system will not exceed 16km/h (4.4m/s) if a pedestrian is within 4.5 meters away. It will then come to a stop, 1.5 meters from the pedestrian, while the pedestrian is in the collision zone. It will stay stopped until the pedestrian is no longer in the collision zone. Once the pedestrian is no longer in the path of the autonomous vehicle the PCAS shall no longer notify the Vehicle Brake by Wire System to stop the car. The car will then accelerate at a steady rate of 0.25g, accelerating at 2.45m/s, until the autonomous vehicle reaches its steady state speed of 50km/h (13.89 m/s). This shall happen within 5 seconds of the pedestrian no longer being in the path of the autonomous vehicle.

Figure 8: PCAS Prototype Case Two Screen

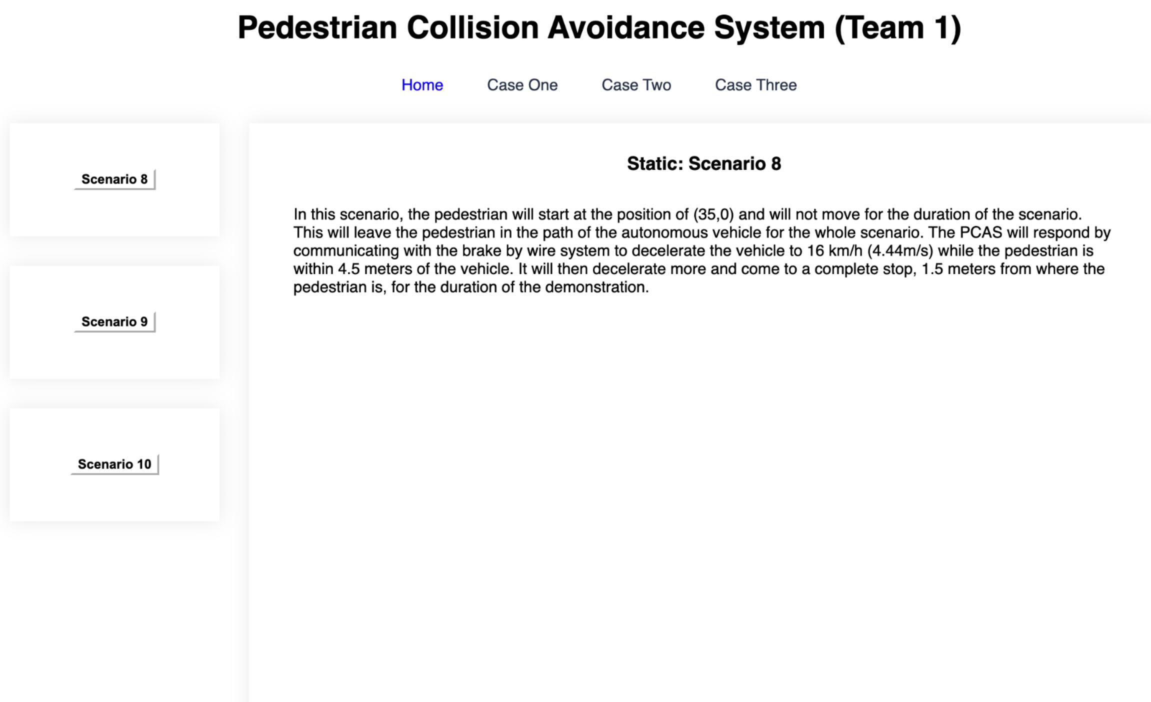


Figure 9: PCAS Prototype Case Three Screen

5.2 Sample Scenarios

This section introduces 10 different scenarios that are demonstrated in the PCAS prototype. These scenarios were given to us by the customer and have been detailed in the prototype. A description of each scenario and how the PCAS will react to the scenario is detailed below. All of the scenarios have some consistencies with both the autonomous vehicle and the pedestrian. The autonomous vehicle in all scenarios will have an initial steady state velocity that is controllable with the brake by wire system. It will always be heading straight along the +x axis. It will always start at the origin(0,0). The pedestrian will always have a static or constant speed in a direction parallel to the y axis. Their initial position will always be (35,7). Figure 5 below shows the coordinate system for the scenarios as given by the customer.

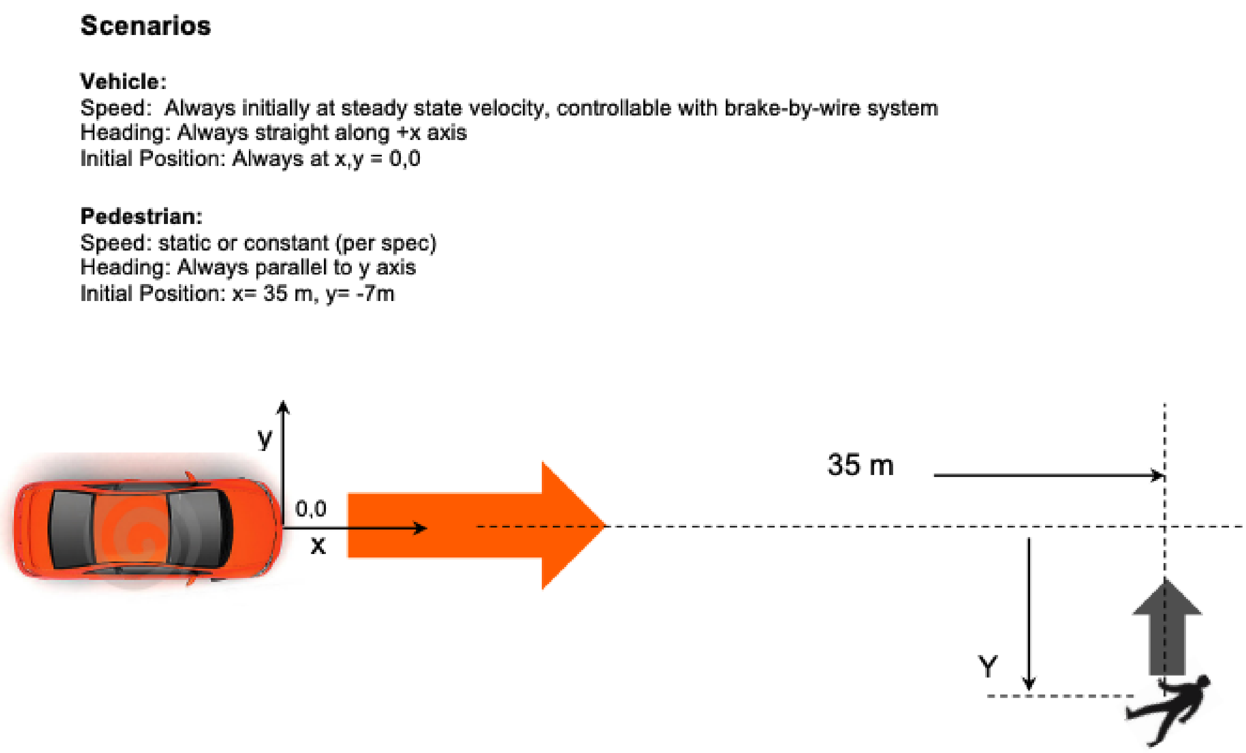


Figure 5: Axis for the scenarios

5.2.1 Scenario 1: Moving Then Stopped

In this scenario the Pedestrian will be moving in the positive y direction with an initial speed of 10 kilometers per hour. They will begin at (35,-7) and continue until they come to a stop at (35,0) giving them a final speed of 0 kilometers per hour. This leaves the pedestrian stopped directly in the path of the autonomous vehicle. In this scenario the PCAS will input the data from the stereo camera and communicate with the brake by wire system to stop the autonomous vehicle 1.5 meters before it collides with the pedestrian.

5.2.2 Scenario 2: Moving Then Stopped at Position (35,-2)

In this scenario the Pedestrian will be moving in the positive y direction with an initial speed of 10 kilometers per hour. They will begin at (35,-7) and continue until they come to a stop at (35,-2) giving them a final speed of 0 kilometers per hour. This leaves the pedestrian within the collision zone. This is because the width of the autonomous vehicle is 2.0 meters wide. In this scenario the PCAS will input the data from the stereo camera and communicate with the brake by wire system to stop the autonomous vehicle 1.5 meters before it collides with the pedestrian.

5.2.3 Scenario 3: Moving Then Stopped at Position (35,-3)

In this scenario the Pedestrian will be moving in the positive y direction with an initial speed of 10 kilometers per hour. They will begin at (35,-7) and continue until they come to a stop at (35,-3) giving them a final speed of 0 kilometers per hour. The pedestrian does not end in the collision zone. This is because the width of the autonomous vehicle is 2.0 meters wide. In this scenario the PCAS will input the data from the stereo camera and determine that it needs to slow down but will not come to a complete stop because when the pedestrian stops the stereo camera will detect that they have stopped and are not in the collision zone.

5.2.4 Scenario 4: Moving Then Stopped at Position (35,-5)

In this scenario the Pedestrian will be moving in the positive y direction with an initial speed of 10 kilometers per hour. They will begin at (35,-7) and continue until they come to a stop at (35,-5) giving them a final speed of 0 kilometers per hour. The pedestrian does not end in the collision zone. This is because the width of the autonomous vehicle is 2.0 meters wide. In this scenario the PCAS will input the data from the stereo camera and determine that it needs to slow down but will not come to a complete stop because when the pedestrian stops the stereo camera will detect that they have stopped and are not in the collision zone.

5.2.5 Scenario 5: Static for 1.5 Seconds Then Moving

In this scenario the Pedestrian will initially be stopped at the position (35,0) and have a delay of 1.5 seconds before moving and ending with a final speed of 10 kilometers per hour. This will leave the pedestrian directly in the vehicle's path for 1.5 seconds and then continue moving until it is out of the path of the autonomous vehicle. The PCAS will react to this by slowing down and stopping until the pedestrian is no longer in the collision zone. It will then accelerate and return to its initial velocity

5.2.6 Scenario 6: Static for 1.8 SecondsThen Moving

In this scenario the Pedestrian will initially be stopped at the position (35,-2) and have a delay of 1.8 seconds before moving and ending with a final speed of 10 kilometers per hour. This will leave the pedestrian directly in the vehicle's path for 1.8 seconds and then continue moving until it is out of the path of the autonomous vehicle. The PCAS will react to this by slowing down and stopping until the pedestrian is no longer in the collision zone. It will then accelerate and returning to its initial velocity

5.2.7 Scenario 7: Static for 1.1 SecondsThen Moving

In this scenario the Pedestrian will initially be stopped at the position (35,-4) and have a delay of 1.1 seconds before moving and ending with a final speed of 10 kilometers per hour. In this scenario the pedestrian will never be in the path of the autonomous vehicle so the PCAS does not have to communicate with the brake by wire system and the autonomous vehicle will continue at its initial velocity.

5.2.8 Scenario 8: Static With Position (34,0)

In this scenario the Pedestrian will start at the position of (35,0) and will not move for the duration of the scenario. This will leave the pedestrian in the path of the autonomous vehicle for the whole scenario. The PCAS will respond by communicating with the brake by wire system and stopping the vehicle for the duration of the demonstration.

5.2.9 Scenario 9: Static With Position (35,-2)

In this scenario the Pedestrian will start at the position of (35,-2) and will not move for the duration of the scenario. This will leave the pedestrian in the collision zone for the whole scenario. The PCAS will respond by communicating with the brake by wire system and stopping the vehicle for the duration of the demonstration.

5.2.10 Scenario 10: Static With Position (35,-4)

In this scenario the Pedestrian will start at the position of (35,-4) and will not move for the duration of the scenario. For this scenario the pedestrian will never be in the path of the autonomous vehicle and will not be moving so the PCAS does not need to communicate with the brake by wire system and the autonomous vehicle will continue with its initial velocity.

6 References

[1] C. Capaldi, “Automated Vehicle Algorithm for Pedestrian Collision Avoidance Function.” Dataspeed, Rochester Hills, MI.

[2] Cheng, Betty. "*Project Overviews and Team Roles*" Online. Michigan State University, 20 Oct. 2022, Michigan State University. Lecture.

7 Point of Contact

For further information regarding this document and project, please contact **Prof. Betty H.C. Cheng** at Michigan State University (chengb@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.