Software Requirements Specification (SRS)

Pedestrian Collision Avoidance System

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1 Introduction

The auto industry has had an intense interest in autonomous or highly automated driving. This requires 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 will give an in-depth outline of how the customers requirements were interpreted 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 system 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 system uses camera and failsafe sensor output from the vehicle to carry out responses necessary to ensure that the condition is met that no pedestrian collisions occur.

Using the camera and failsafe sensor output, the PCAS system will detect pedestrians in the path of the vehicle and will decelerate the vehicle as necessary whilst alerting the driver. The driver has the ability to override the PCAS system'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 system will remain inactive. In the event of a pedestrian collision, legal liability will not be placed on the PCAS system.

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):**
- **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 two describes the PCAS system. Next, Section three describes the system's specific requirements, including global invariants, system requirements, and cybersecurity requirements. Section four describes the modeling requirements. This includes the use case diagram, domain model, and sequence diagram, along with detailed descriptions that model the system's operation. Lastly, section five demonstrates different scenarios the PCAS system may encounter using a prototype.

2 Overall Description

This section will be focusing on describing the main functionalities and dependencies of the PCAS system.

- Product Perspective

- Product Function
- User Characteristics
- Constraints
- Assumptions and Dependencies
- Apportioning of Requirements

2.1 Product Perspective

The Pedestrian Collision Avoidance System (PCAS) is responsible for the complete mitigation of pedestrian collisions with the vehicle in which it operates while at steady state velocity. The implementation of a collision avoidance system while 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 system.

As the PCAS system is an embedded subsystem of the vehicle in which it operates, it relies on a number of components of the vehicle, such as the vehicle's camera sensors. Because of this, the PCAS system cannot function properly on its own. The PCAS system 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 system interacts with various vehicle components in order to alert the driver of a pedestrian within its path, for example by playing alert sounds through the car's speakers.

System Architecture:

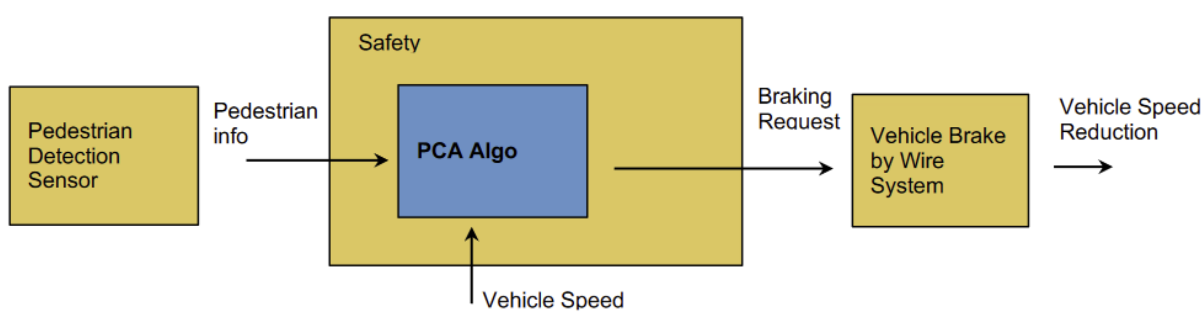

Figure 1: System Architecture

2.2 Product Functions

The PCAS will be paired with an autonomous or highly automated vehicle to handle a fundamental aspect of driving. This fundamental aspect is avoiding collisions with pedestrians at all times. This makes its 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 a stereo camera and the brake by wire system. The stereo camera will be positioned on the front of the car in a location that gives a view that encompasses 180 degrees of the autonomous vehicles 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 be monitoring the packets of information it is receiving 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 alter the user by making a beeping sound and vibrating the seat. Both of these are already functions of the car 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.

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 system in order to ensure maximum safety and reliability. First, 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. Any 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 system 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

- Assumption 1: The PCAS system 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 pedestrian will have the following characteristics and shall be detected and avoided by the PCAS system:
    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 system shall activate within 0.25 seconds.
4. The PCAS system 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 system a packet of information every 100ms (the cycle time of the stereo camera).
    5.1. The packet of information given to the PCAS system 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 system shall determine when the vehicle needs to brake using the stereo camera outputs.
    6.1. The PCAS system 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 system shall ensure that the vehicle decelerates such that the autonomous vehicle does not exceed 16kph within 4.5m of the pedestrian. The PCAS system 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 system 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. responded 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 .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 system shall continue to recalculate and evaluate the output from the stereo camera. This will account for the conditions of the road. If the car 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 system shall communicate with the vehicle's alarm warning system to alert the user with a beeping sound and by vibrating the seat.
9. If the Driver wishes 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. This will turn off the PCAS so it is no longer liable for any collisions.
10. After the vehicle comes to a complete stop the system shall keep the car 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 system shall no longer notify the Vehicle Brake by Wire System to stop the car and allow the car 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 not 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), 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

15. The PCAS system meets performance requirements despite weather, lighting, and poor road conditions.
16. The PCAS system must always avoid collisions.
17. 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.
18. The PCAS system must minimize lost time

18.1. “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”

19. The vehicle shall not exceed 16 kph if an obstacle is detected within 4.5m

3.3 Cyber Security Requirements

4 Modeling Requirements

This section presents various diagrams and their corresponding descriptions to depict key elements, interactions, scenarios, and services of the PCAS system 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 System and the corresponding use case descriptions. A use case diagram captures a user’s visible function and interaction with the system. The use case descriptions describe each use case in the use case diagram 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 saying 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.

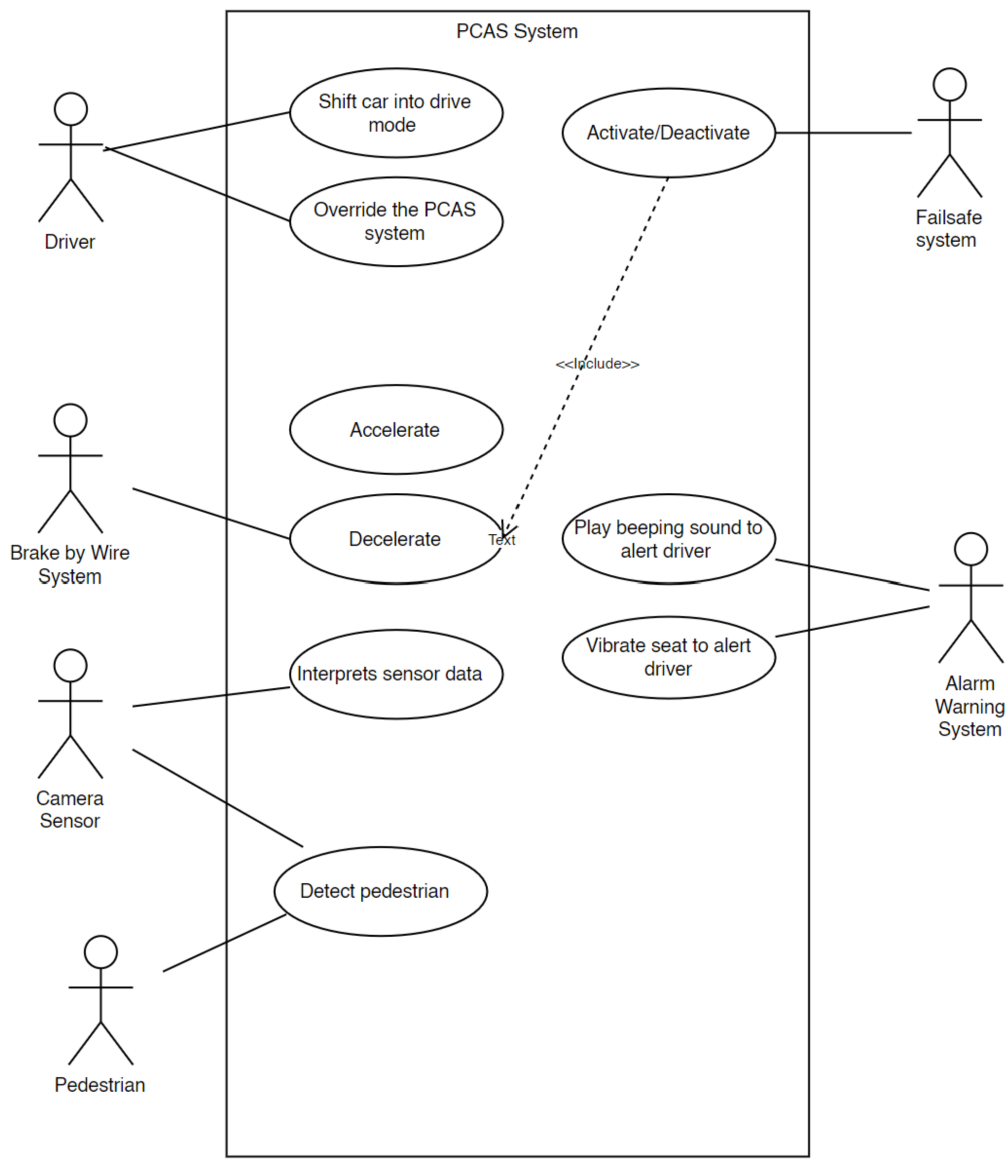

Figure 2: Use Case diagram for PCAS

4.1.1 Use Case Descriptions

Tables 1 through Table 7 detail the individual use cases depicted in Figure 2. The tables will provide a comprehensive description for each individual use case. The “Use Case” row in the table will give a title for that use case. The “Description” row will give a brief overview for that specific use case. The “Type” row will categorize the use case to either primary or secondary. The “Includes” and “Extends” rows will indicate whether or not other use cases are related to this one. The “Cross-refs” row will list the requirements from Section 3 that are included in this use case. The last row, “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 system turns on and enters a suspend mode as the autonomous vehicle is not yet shifted to a drive state.
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 car 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, 4, 5
Use cases:	Turn on the car

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

Use Case:	Autonomous Vehicle in Drive
Actors:	Driver, Stereo Camera
Description:	When the autonomous vehicle is in drive the stereo system should be communicating with the PCAS sending packets of information every 100 milliseconds. The PCAS is continuously analyzing these packets of information 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:	4, 5, 12, 14, 15, 16, 17, 18, 19
Use cases:	Turn on the car, Shift Autonomous Vehicle to Drive

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

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 4: Use case description for *Detect Pedestrian*

Use Case:	Brake Autonomous Vehicle
Actors:	Braking System
Description:	When the PCAS determines it needs to brake it will tell the brake by wire to slow down the autonomous vehicle.
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	1, 6, 7, 10, 16, 17, 19
Use cases:	N/A

Table 5: Use case description for *Brake Autonomous Vehicle*

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 by a beeping noise and a vibration.
Type:	Primary

Includes:	N/A
Extends:	N/A
Cross-refs:	8
Use cases:	Brake Autonomous Vehicle

Table 6: Use case description for *Alert Driver*

Use Case:	Driver Override
Actors:	Driver
Description:	If the Driver wishes to override the system they will need to press the brake pedal and take control of the autonomous vehicle's speed. This will turn of the PCAS so it is no longer liable for any collisions
Type:	Primary
Includes:	N/A
Extends:	N/A
Cross-refs:	8
Use cases:	Brake Autonomous Vehicle

Table 7: Use case description for *Driver Override*

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.

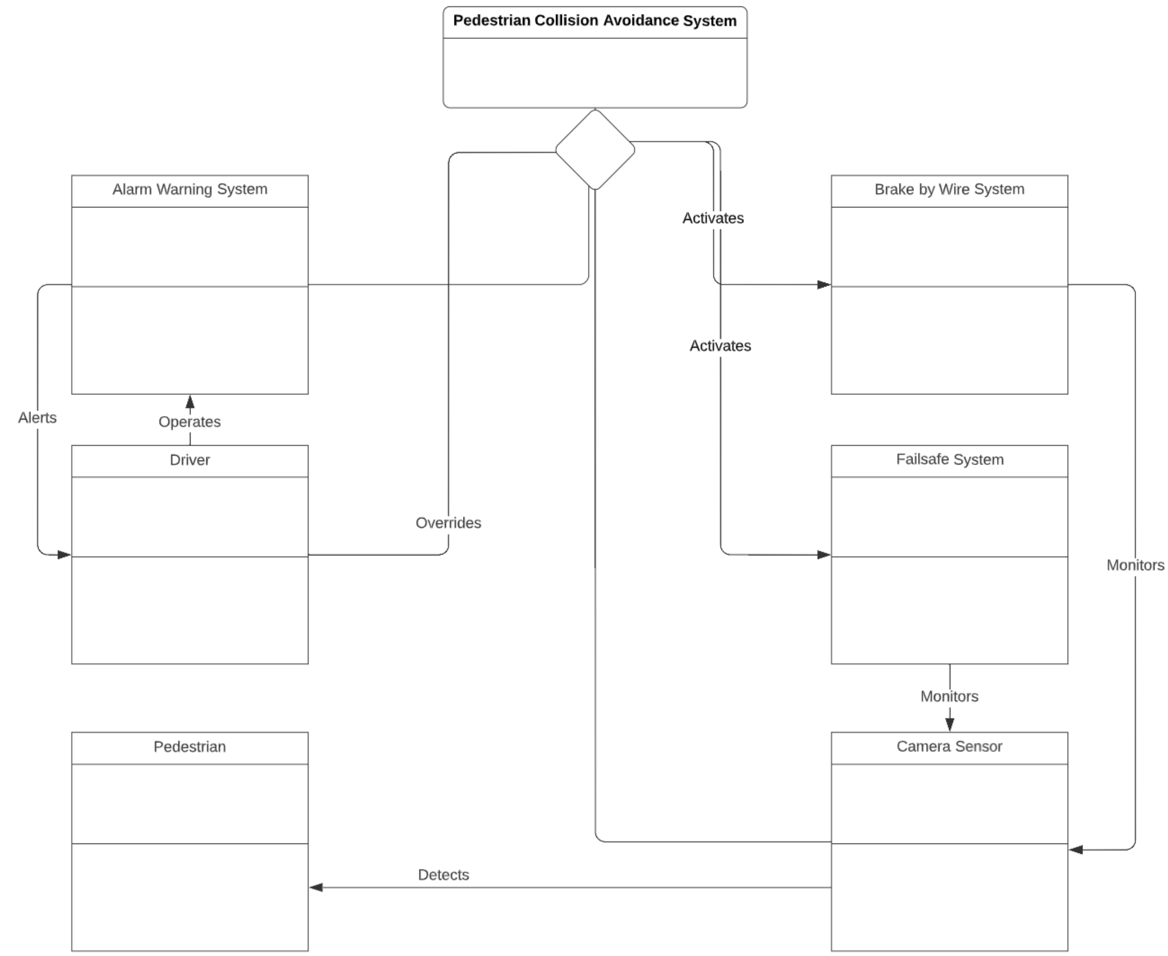

Figure 3: Domain Model for PCAS

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 welcome screen in which the user will then navigate to the prototype using the *Prototype* button. From here there will be a drop down menu in which you can choose any of the ten scenarios and click the *run* button. The scenario will then run and show how the PCAS will react to the given scenario. Figure 4 below shows a picture of the prototype.

Figure 4: PCAS Prototype

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 system 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.

Scenarios

Vehicle:
Speed: Always initially at steady state velocity, controllable with brake-by-wire system
Heading: Always straight along +x axis
Initial Position: Always at x,y = 0,0

Pedestrian:
Speed: static or constant (per spec)
Heading: Always parallel to y axis
Initial Position: x= 35 m, y= -7m

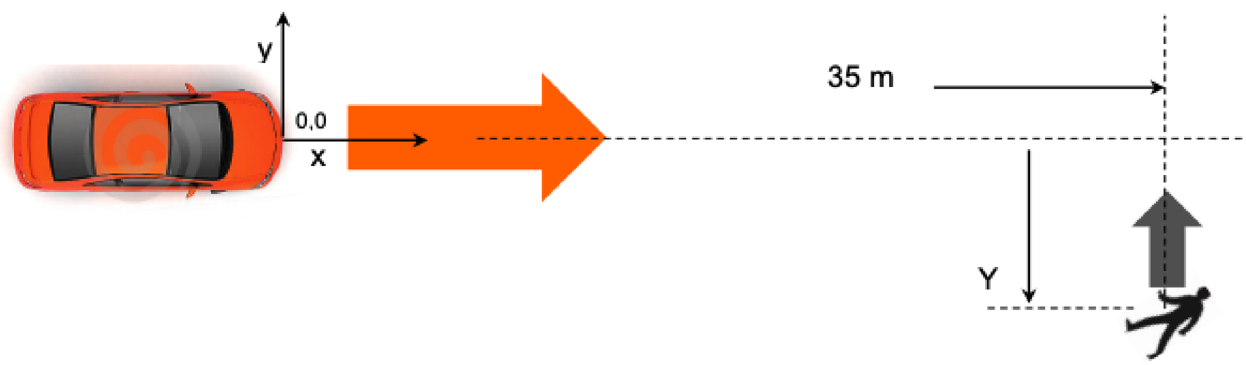

Figure 5: Axis for the scenarios

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

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

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

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 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 system 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

5.2.6 Scenario 6: Static Then 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 system 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 Then 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

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

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

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

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[1] D. Thakore and S. Biswas, "Routing with Persistent Link Modeling in Intermittently Connected Wireless Networks," Proceedings of IEEE Military Communication, Atlantic City, October 2005.

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.