DEVELOPMENT OF BLIND SPOT DETECTION SYSTEM FOR HEAVY VEHICLE

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**A thesis submitted
in fulfillment of the requirements for the degree of
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DEDICATION

First of all, I would like to express my gratitude to Allah for providing me with the strength necessary to complete this research and see my thesis become reality. This study and research dedicated to my beloved parents, Muhammad Sabri bin Ahmad Nazri as Asmawati binti Ahmad who have always supported and encouraged me in completing my study. Not forget to mention my siblings, supervisor Ir.Ts.Dr. Mohamad Hafiz bin Harun, and my friends who have supported me throughout my education journey. Thank you for all your assistance, which I will always appreciate and will never forget.

ABSTRACT

Vehicle accidents often occur along the roadway due to machine and human factors. Compared to all types of vehicle accidents, accidents involving heavy vehicles are more likely to be fatal than others. There are various aspects that affect driver injuries and fatalities. This thesis elaborates on the development of blind spot detection for heavy vehicles by implementation of simulation based data in creating a device that is able to detect a vehicle passing or staying inside the blind spot of heavy vehicles, especially those with bigger sizes affecting their blind spot area, thus increasing the hazard while driving or being near it. Vehicle Blind Spot Detector (VBSD) for heavy vehicles uses a microcontroller, receiver, and actuator to provide a system that enables it to recognise heavy vehicle blind spots and detect a vehicle. The condition of the blind spot varies in size, turning, and the normal condition of a heavy vehicle. The blind spot, also known as "no zones," was divided into front, rear, and sides. However, the sides determine whether the driver was left-hand drive (LHD) or right-hand drive (RHD). Based on research, there is higher visibility on the driver side than the passenger side. Therefore the simulation propose a left side sensor positioning. The driver must be extra careful to avoid any unwanted collision with another vehicle when making an action, including speeding, slowing, and lane changing. The front side is predicted to be 20 feet from the front bumper and 30 feet from the rear bumper or trailer in managing the blind spot area. The idea was developed through computer simulations, and test results were used to confirm it. The device's effectiveness is limited to addressing unsafe motions that develop gradually, such as those seen during on-ramp manoeuvres, due to its passive nature, which necessitates the driver taking corrective action. Truck Sim by Mechanical Simulation offers a procedure related to blind spot detection in ADAS category in determining the blind spot of a truck. Then embed the data into MATLAB/Simulink to propose a way to create a algorithm to send into a microcontroller to be a blind spot detection device. By using Arduino Due as a microcontroller and an ultrasonic sensor HC-SR04 as the sensor that transmitted a wave to the object and reflected back to receive the duration of the signal transferred and thus calculate the distance of the object, an indicator warning and a buzzer worked as a warning signal for the driver. Truck Sim provides full-working simulation of a real-time mechanical simulation that is suitable for obtaining result. This software create procedure technique to determine the quickest time response for sensor detection was offered by prior researchers. The blind spot detection system for heavy vehicles simulates the optimum placement of sensors based on data gathered from accidents involving blind spots and the experimental sensor position on the heavy vehicle body. Therefore, we will determine the optimum position for sensor and analyze blind spot detection system configuration. The capability to run software simulation enables researchers to minimise cost and list out test findings before fabricating and creating the hardware of the VBSD, which greatly lowers blind spot accidents.

ABSTRAK

Kecelakaan kenderaan sering berlaku di sepanjang jalan kerana faktor mesin dan manusia. Dibandingkan dengan semua jenis kemalangan kenderaan, kemalangan yang melibatkan kenderaan berat lebih cenderung menjadi maut daripada yang lain. Terdapat pelbagai aspek yang mempengaruhi kecederaan parah pemandu.. Tesis ini membincangkan pembangunan pengesanan titik buta untuk kenderaan berat dengan melaksanakan data berasaskan simulasi dalam mewujudkan peranti yang boleh mendeteksi kenderaan yang lewat atau tinggal di dalam titik buta kenderaan besar, terutamanya yang mempunyai saiz yang lebih besar yang mempengaruhi kawasan titik buta mereka, dengan itu meningkatkan bahaya semasa memandu atau berada di dekatnya. Vehicle Blind Spot Detector (VBSD) untuk kenderaan berat menggunakan mikropengawalr, penerima, dan penggerak untuk menyediakan sistem yang membolehkan ia mengenali titik buta kenderaan yang berat dan mendeteksi kenderaan. Keadaan titik buta berbeza-beza dalam saiz, berputar, dan keadaan normal kenderaan berat. Titik buta, juga dikenali sebagai "no zone", dibahagikan kepada depan, belakang, dan sisi. Walau bagaimanapun, pihak-pihak menentukan sama ada pemandu adalah drive kiri (LHD) atau drive kanan (RHD). Berdasarkan kajian, terdapat penglihatan yang lebih tinggi di sisi pemandu daripada di sisi penumpang. Oleh itu, simulasi ini mencadangkan penempatan sensor sisi kiri. Pemandu mesti berhati-hati untuk mengelakkan sebarang tabrakan yang tidak diingini dengan kenderaan lain apabila mengambil tindakan, termasuk kelajuan, melambatkan, dan perubahan laluan. Sisi hadapan dijangka 20 kaki dari bamper hadapan dan 30 kaki daripada bumper belakang atau pengekor dalam menguruskan kawasan titik buta. Idea ini telah dibangunkan melalui simulasi komputer, dan hasil ujian digunakan untuk mengesahkan ia. Keberkesanan peranti ini terhad kepada menangani pergerakan yang tidak selamat yang berkembang secara beransur-ansur, seperti yang dilihat semasa lintasan di jalan raya, kerana sifat pasifnya, yang memerlukan pemandu mengambil tindakan pembetulan. Truck Sim by Mechanical Simulation menawarkan prosedur yang berkaitan dengan pengesanan titik buta dalam kategori ADAS dalam menentukan titik buta sebuah truk. Kemudian membenamkan data ke dalam MATLAB/Simulink untuk mencadangkan cara untuk mencipta algoritma untuk menghantar ke dalam mikropengawal untuk menjadi peranti pengesanan titik buta. Dengan menggunakan Arduino Due sebagai mikropengawal dan sensor ultrasonik HC-SR04 sebagai sensor yang menghantar gelombang ke objek dan mencerminkan kembali untuk menerima tempoh isyarat yang dihantar dan dengan itu mengira jarak objek, amaran indikator dan buzzer berfungsi sebagai isyarit amaran untuk pemandu. Truck Sim menyediakan simulasi kerja penuh simulasi mekanikal masa nyata yang sesuai untuk mendapatkan hasil. Perisian ini mencipta teknik prosedur untuk menentukan masa sambutan tercepat untuk pengesanan sensor yang ditawarkan. Sistem pengesanan titik buta untuk kenderaan berat mensimulasikan penempatan sensor yang optimum berdasarkan data yang dikumpulkan daripada kemalangan yang melibatkan titik buta dan kedudukan sensor percubaan pada badan kereta berat. Oleh itu, kami akan menentukan kedudukan optimum untuk sensor dan menganalisis konfigurasi sistem pengesanan titik buta. Keupayaan untuk menjalankan simulasi perisian membolehkan penyelidik untuk meminimalkan kos dan senarai temuan ujian sebelum membina dan mewujudkan perkakasan VBSD, yang sangat mengurangkan kemalangan titik buta.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
VBSD	-	Vehicle Blind Spot Detector
NHTSA	-	National Highway Traffic Safety Administration
WHO	-	World Health Organization
GDP	-	Gross Domestic Product
MIROS	-	Malaysian Institute of Road Safety Research
ADAS	-	Advanced Driver Assistance System
ESV	-	Enhanced Safety of Vehicles
BSD	-	Blind Spot Detection
EMC	-	ElectroMagnetic Compatibility
SUT	-	Single Utility Trucks
FMCSA	-	Federal Motor Carrier Safety Administration
LED	-	Light Emitting Diode
FOT	-	Free on Truck
CWS	-	Collision Warning System
CPU	-	Central Processing Unit
D	-	Distance
R	-	Propagation velocity (Rate) in air (speed of sound)
T	-	Time
DC	-	Direct Current
BSD	-	Blind Spot Detection
BSZ	-	Blind Spot Zone

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CHAPTER 1

INTRODUCTION

1.1 Background

Human discovered transportion back to the earliest days of human civilization. It contributes to our society in many aspects helps us emerged at different times and different regions, contributing to the interconnected world.

Road vehicles improves day by day in terms of safety features that helps prevent road accident from happen. However, the latest record shows that highway collisions are unavoidable. According to the World Health Organization (WHO), globally, road traffic accident account for approximately 1.35 million deaths each year (STOWMAN, 1949). This means that on average, over 3,700 people lose their lives every day due to road accidents and traffic fatality rates in the world increases as well as crash injuries were the top causes of death among age 5-29 (Akmal, 2016).

Crash injuries predicted to be the eight largest cause of morality globally and accident claim more lives than HIV/AIDS. Futhermore, fatal and non-fatal collision injuries cost approximately $1.8 trillion between 2015 and 2030 with the amounts to a 0.12 % yearly tax on world gross domestic product, GDP. A high income country has a lower death rate than a low income country and the following years from 2013 to 2016, there were no declines in the number collision fatality.

Meanwhile estimated around 200 people die each year in United State as a result of road fatalities abroad. The NHTSA statistics provide insights of road accident data and the contributing factor including driver distraction, speeding and driver negligence that would be the causes of crashes. NHTSA reported there were 42,939 people killed in motor vehicle traffic crashes on U.S. roadways during 2021, a slight increase of 10% from 39,007 fatalities in 2020, resulting more killed people in 2021 (Hs, 2023). On research note Traffic Safety Facts by NHTSA, said that motor vehicle traffic crashes was the leading cause of death in 2016 and 2017. The trends show from figure 1.1 fatalities number as the ranks from 1981 to 2017 and for the ninth consecutive year, motor vehicle traffic crashes 2017 were not among the top 10 deatth causes in United States.

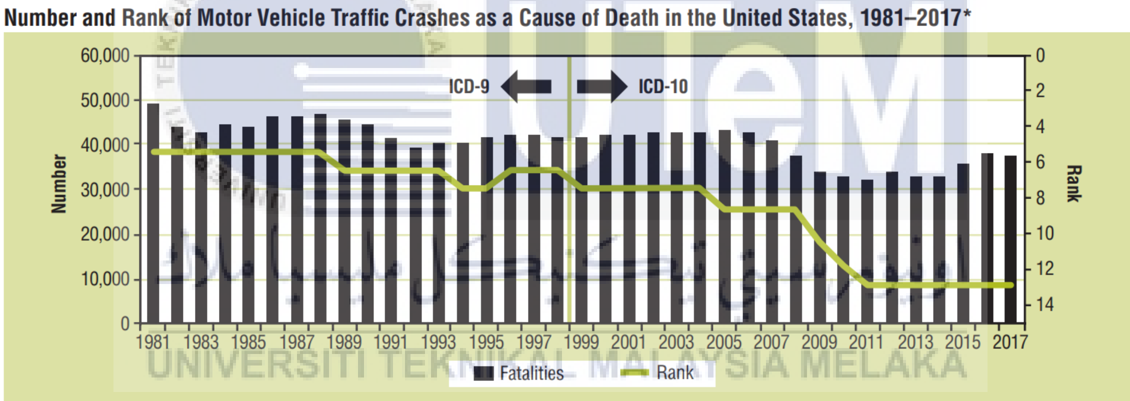


Figure 1-1 - Number and Rank of Motor Vehicle Traffic Crashes as a Cause of Death in the United States, 1981–2017

In Malaysia, there were around 100,000 reported road accidents involving truckers in 2021 in different age group 0–14-year-olds are the youngest age group, followed by 35–64-year-olds. The young (15–34) and the elderly (over 65) are two demographic groups that require additional attention. Head-on and rear-end collisions were the most common types of road crashes, according to in-depth examinations by the Malaysian Institute of Road

Safety Research (MIROS) into high-profile events with 32.8 percent and 28.4 percent of all crashes, respectively, rear-end collisions were the most frequent crash types. Only 3.5% of rollover incidents happened throughout the time. Estimated average trends showed a 51 percent fatal rear-end collision rate during the day and a 49 percent fatal rear-end collision rate at night. However, during the night, locations without lighting were the scene of roughly 55,1% of collisions. This showed that low lighting-induced impaired vision might be the main factor contributing to rear-end crashes (L a p o r a n Ta h u n a n 2021, 2021).

According to report acording to Transport Minister Datuk Seri Dr Wee Ka Siong on paultan.org news, 255,532 road accidents occurred in Malaysia from January to September 2021, Police report statistics said, 3,302 of these were fatal (Mohan K Ramanujan, 2022).

Several factor that contributed to road accident or crash happened such as head on crash, hitting an object or pedestrian, side impact crash, rear impact, blindspot failure and many more. Vehicle have many specification and different sizes which each vehicle have its own configuration in determining their own parameter in safety technology equipment, this is easy for cars due to their frequecy of mass production and being a consumer to all human these mordern days. For heavy vehicles such as trucks, truck semi-trailer might have much different parameters compared to cars. The configuration of truck is more complicated as cars we can only depend on side mirror and field of view is much bigger compared to heavy vehicle. Current safety technology use is known as Advanced Driver Assistance System (ADAS) that assist drivers driving consists of electronic technology that increases road safety for all types of vehicles. Most crucial was the blind spot detection system that enables driver enhance their field of view around their vehicle which help with driver decision making while driving on the road in ensuring safety for every road user.

1.2 Problem Statement

Automotive industries has provided innovation for safety and grown exponentially as times flow, howerver in aspect of truck innovation system has been stagnant. Heavy vehicle are more likely to have a high chance of fatal accident with other road users since heavy vehicle have a high size tolerant compared to others. On news, we have told that many accident involving heavy vehicles with cars, motorcycles and other smaller pedestrians caught due to the heavy vehicle driver visibily loss that is known as blind spot exist within large area around the vehicle. Studies show that lorry drivers believed they drove more cautiously when a motorcycle was riding close to the lorry. On the roadway, heavy vehicle was the biggest in terms of size and displacement, it can go fast in a second, however the carried weight has to be the disadvantages and thats why heavy vehicle such as truck, semi-trailer and other carefully drove on the roadway, while one other possible hazard that most likely dangerous as the vehicle get bigger in size has larger area of blindspot.

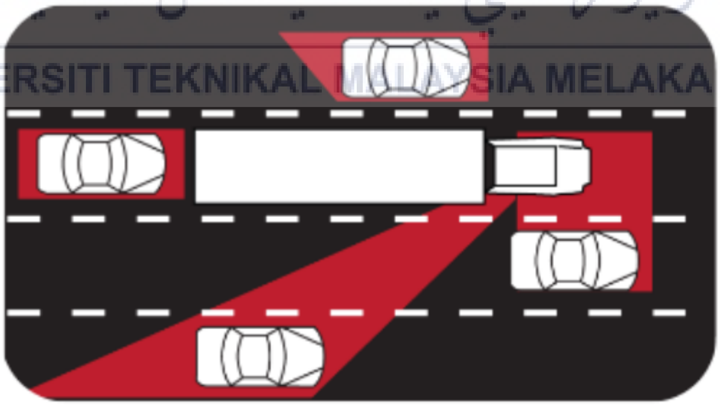


Figure 1-2 - Heavy vehicle Blindspot Visualized (Santhoshkumar et al., n.d.)

Most often truck drivers did not cast a glance upon their blind spot mirrors before as well as during their maneuvers at the intersection (Jansen & Varotto, 2022). Heavy vehicle blindspot area is bigger compared to another type of vehicle. (Prati et al., 2018)

This configuration became a huge problems when driving up in the roads where every type of transport combine in a same road and the result will create a huge caution area whereas driver need to be much as careful as possible with surroundings. The aspect of safety decreases especially for the small vehicle such as motocycle which have the high risk of colliding with heavy vehicle such as truck trailer and container, that have much a bigger blindspot which was a problem to the driver visibility. Most car nowadays have the blind spot detection built in inside, same for heavy vehicle semi-trailer. However in roadway we can see less usage of the blind spot detection system because the it only available on the new model of heavy vehicle used on the road. This potential hazard can lead to fatal accidents involving heavy vehicle.

Due to high rate of crashes involving heavy vehicles with smaller vehicle due to blind spot, a lot of research on blind spot detection for heavy vehicle introduced, example developement of device prototype for a car blind spot detection (Z., Hassan, 2020), which able to detect object in blind spot region and give three output based on early warning devices and react as a early warning to alert the driver. Meanwhile Pitchipoo. P.(Pitchipoo et al., 2014), proposed a decision model to optimize blind spot in heavy vehicle by improves the area of visibilites through by designing and optimizing parameters used in the rear view mirror for heavy vehicle. However, on This method has generated concerns about the algorithm's practicality because it will be subject to limitations on vehicle threshold due to blind spot region were different depending on type of heavy vehicle models.

Figure 1-3 - Different type of primemover for semi trailer front no zones

The type of vehicle, the position of the blindspot region of the heavy vehicle are a few of the primary causes of vehicle blind spot (Astonkar et al., 2022).An important factor in vehicle blind spot action in semi-trailer truck was the length of its trailer. Because of the length of trailer increase the visibility and the blind spot region became farther and larger, making the driver and trailer are virtually and visibly completely separated. Due to this circumstance, the driver is unable to take timely remedial action because they are uninformed of the trailer's blind spot region area around the vehicle. Road accident causes in Malaysia in 2011 are depicted in Figure 1.1 by the Malaysian Institute of Road Safety Research (MIROS), with human error accounting for 80.6% of the causes, road conditions accounting for 13.2%, and vehicle condition accounting for only 6.2% (23). As a result, the initial indication proposed in this study to boost driver awareness and provide assistant to the driver the time to take corrective action improves the driver's sensitivity and visibility to the vehicle blind spot region area.

Figure 1-4 - Malaysia road accident factors in 2011

A truck-semitrailer vehicle's initial warning indication system can be created by taking into account a precise heavy vehicle model. The truck-semitrailer model is created to mimic the behaviour of a real vehicle on the real road situation. However, previously there is a constraint in the truck-semitrailer models that have been created by various academics.

During a turn, the driver can see the road directly via the front windows and indirectly through the rearview mirrors (Moore, D.N. 2011 & Jannat, M. 2020). There are several blind zones for drivers around the truck, nevertheless, because of the limitations imposed by the truck's structure (Niewoehner, W 2005).

In research particular, when turning right, the trailer produces a significant offset with respect to the tractor part, increasing the inner wheel difference blind zone and obstructing the right rearview mirror due to the trailer body. These elements undoubtedly increase the posibility danger of accidents (Q. Wang et al., 2022). By gathering all the posibilities blind spot area on the truck semi-trailer body, optimum blind spot sensor placement can be determine to minimize the risk of accident and increase driver visibility while driving or inside the heavy vehicle. Therefore, this can improve the initial warning indicator and time respond will be faster, thus the driver has the most sufficent time to perform corrective action and avoid any collision. Modern intellegent blind spot detection can factor in time detection measure, position, vehicle dimension and layout when calculating blind spot detection area threshold. By integrating the blind spot area in determining the optimum position for sensor, the accuracy and ultility for the blind spot detection system for heavy vehicle may increased greatly. In blind spot detection range, a real-time detection prediction used to determine an object present inside the blindzone area. As a result this research will offer the various optimum positions of sensor placements for detection and warning devices that can notify the driver to make decision and reaction.

1.3 Objectives

The main aim of this research is to develope a blind spot detection system for heavy vehicle. Specifically, the objectives are as follows:

a) To develop sensor positioning for heavy vehicle blind spot detection system.

b) To identify the sensor position for early warning indication.

1.4 Scope of Research

Based on objectives, The scope of this research are defines as follows:

1. The blind spot sensor positioning method using time response on each different location.
2. The best blindspot position is analyzed to improve sensitivity of sensor.
3. The heavy vehicle blind spot positioning method is measured by run experiment between passby object.

4. To identify the sensor position for early warning indication.

5. A microcontroller is applied to construct a blind spot detection system device.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The creation of advanced driver assistance systems (ADAS), which aim to reduce accidents and improve road safety for all, has become crucial in the field of automobile safety. The Blind Spot Detection system (BSD), which was created expressly to solve the difficulties faced by large vehicles, is an important component of this pursuit. The blind areas surrounding big vehicles provide a serious risk to both the drivers and other road users as we travel the busy highways and city streets. These enormous vehicles' poor visibility makes lane changes, merges, and overtaking maneuvers potentially hazardous. However, technology advancements have worked to address this problem by creating intelligent BSD systems that help drivers successfully detect and monitor their blind zones but as there are more vehicles on the road, there are also more accident reported, including accident when lanes changing and blind spot. This section compilation on relevant information related to the entire project. By understanding and comparing relevant information in creating solution and development process.

2.2 Initial Warning Devices

In resolving the issue, researchers and engineers have found the method in prevention technologies. When the BSD sensor detect the incoming vehicle or object pass by, we want to make sure the sufficent time for the actuators to respond effectively when it comes to dangerous circumstances. To prevent vehicle colliding with each other, it is essential to determine the blind spot configuration with it time reaction must be sufficent lead time.

Therefore, initial warning systems are essential for educating and notifying drivers about potential dangers and enhancing road safety. These devices, which are made especially for heavy vehicles, are intended to deal with the difficulties brought on by poor visibility and blind areas and other factor. This is one of the factor that contribute to fatal accident involving heavy vehicle with smaller size vehicle.

(Orlaco Global, 2018) suggests replacing rear-view mirrors on trucks with MirrorEye's video surveillance system (Figure 2-1). The ground-breaking Orlaco system is manufactured in accordance with ISO/TS 16949 standards for the automotive industry and satisfies all ElectroMagnetic Compatibility ,EMC criteria and regulations. MirrorEye's cameras and monitors will be offered for all sorts of trucks at the request of car owners.

Figure 2-1 - Video camera as warning devices (Fitch, G.M. 2011 & Schaudt, 2014).

The employment of video cameras in place of side-view mirrors is a promising development, according to the presented review of data and works (Fitch, G.M. 2011 & Schaudt, 2014).

Although these cameras prevent you from looking ahead of the vehicle, this could lessen the likelihood of a dangerous scenario involving a pedestrian collision in the "blind" areas in front of the vehicle.

Figure 2-2 - (Transparent) pillars of the jaguar

According to company Jaguar Land Rover, the 360 Virtual Urban Windscreen system, for instance, was unveiled by the Jaguar Land Rover group and is intended to increase vehicle visibility (Figure 2-1). The technique enables you to project an image of a section of the road that is obscured by these automotive building components onto the windscreen pillars (Jaguar Land Rover, 2018).

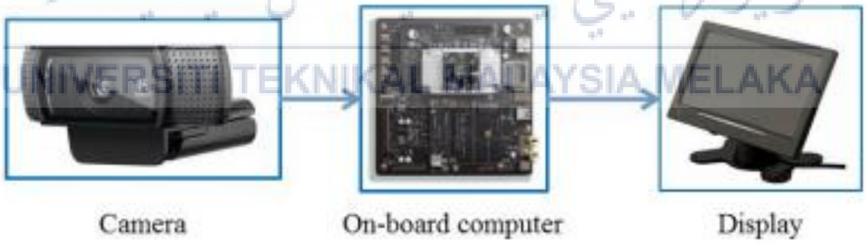


Figure 2-3 - System interaction diagram use for displaying blind spot area

Initial research was done within the parameters of the project (V Makarov, 2017) It was suggested that the displays be integrated into the windscreen pillars of the Gazelle NEXT based on the findings of these works. This method will maintain driver visibility while ergonomically integrating the displays into the car's interior.

Figure 2- 2-4 - Successful braking in front of dummy simulating a pedestrian

The timely delivery of a warning signal to the driver about a potential accident with a pedestrian was the standard for the system's proper operation. The critical situation determination's computed accuracy, which measures the proportion of positive triggers that actually worked, was 0.91. The completeness, which displays the proportion of successful responses to the total number of tests taken, was 0.9. The system's quality was shown by its 89% indicator. Additionally, test races were run without any kind of pedestrian impact warning. The test environment was maintained. A collision happened as a result of the driver's inability to see a pedestrian in their blind spot (Beresnev et al., 2018).

2.3 Vehicle

The vehicle is a form of transportation made to transfer individuals or items from one location to another. Typically, it consists of a chassis, wheels, and a propulsion engine or motor. There are many different types of vehicles, including bicycles, cars, trucks, motorcycles, and buses. Internal combustion engines, electric motors, or alternative fuels can all power them. Vehicles have completely changed how people move around, giving them convenience and mobility while also making it easier to transfer products across long distances. Technology advancement has resulted in the creation of electric and autonomous vehicles, providing more efficient and environmentally friendly options for transportation in the contemporary period.

2.3.1 Type of Heavy Vehicle

A truck semi-trailer comprises of a trailer that is coupled to the truck cab, sometimes referred to as the tractor or prime mover. The truck's back axles support the trailer, which is normally made to transport cargo or freight. The effective transportation of enormous amounts of commodities is made possible by this design. From single utility trucks (SUT) to articulated heavy vehicles with triple trailer combinations, commercial goods vehicles are generally created with a wide range of weights, dimensions, and design patterns. Typically, the towing or lead units, hitches, and one or more towed units are installed on the articulated heavy vehicles. A hitch system links the towing and towed units together.

Examples of hitches or coupling methods include pintle hook connections, kingpin-type connections, and fifth wheels. The constraining forces and moments between the lead unit and the towed units are transmitted via the hitches or coupling devices. Dollies are used to transport additional trailers in a double or triple configuration in the interim. The A-dolly and C-dolly arrangement as seen in (Figure 2-5) is the dollies configuration that is frequently mentioned.

The first semitrailer with a single pintle hitch and the second trailer with a fifth wheel are connected by an A-dolly, a typical single-drawbar dolly. The third trailer's link to the fifth wheel is referred to as the "A-train triples," and this connection is known as the "A-train doubles." As a result, an A-dolly is regarded as a subpar roll-coupling device and permits yaw motion between the dolly and the first trailer. In contrast, C-dollies use robust double drawbars and two pintle hitch connections to essentially eliminate the relative yaw motion between the first trailer and the dolly. For the third trailer connection with a fifth wheel, this sort of connection is referred to as a C-train double or C-train triple. Between the first trailer and the dolly, they also have significant rolling stiffness. For tractor-semitrailer combinations without the A-dolly, C-dolly, or fifth wheel, the second trailer connection is referred to as a B-train double. The lead unit of an articulated heavy vehicle can be a truck or a tractor, and the towed unit might be a trailer or a semitrailer. According to a survey of Canadian trucks, there are seven general families of heavy vehicles that can be classified according to the number of trailers and coupling types. Figure 2-5 shows the schematics of seven generic families of heavy goods vehicles.

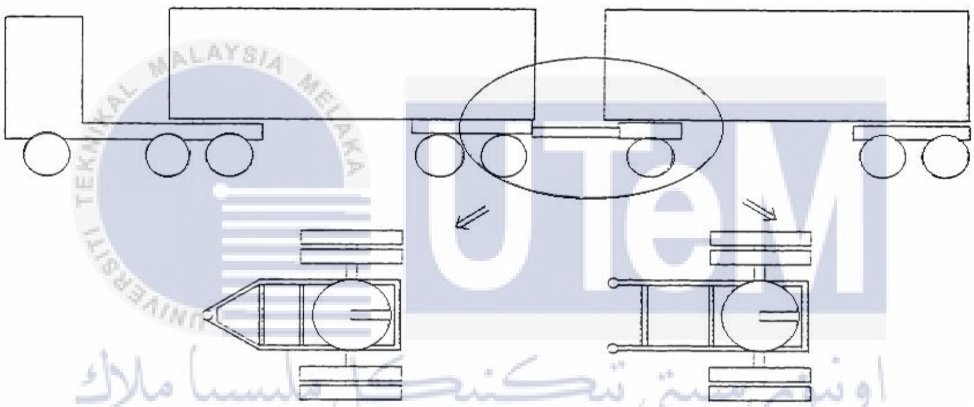


Figure 2-5 - Schematics of single drawbar A-dolly and double draw-bar C-dolly (Liu, 1999)

A tractor-semitrailer unit is the type of commercial freight vehicle that is employed the most frequently. The power unit for the tractor-semitrailer is isolated from the cargo portion by design. Compared to a single utility truck, it offers a more economical and logistically efficient method of transporting goods. As a result, the tractor unit can connect to several kinds of semitrailers with different loads. In the meanwhile, a mechanical coupling, such as a fifth wheel, is utilized to join the tractor unit and semitrailer. The fifth wheel is fixed with a semitrailer kingpin and fitted on the rear tractor chassis frame. The fifth wheel works by enabling the semitrailer to move in pitch, roll, and yaw motion in addition to providing an articulation angle. Figure 2.3 shows the design structure for tractor-semitrailer combinations, which include a tractor, hitch, and semitrailer.

Due to their accessibility during the loading and unloading process, as well as their improved vehicle stability and maneuverability, particularly in reverse, tractor-semitrailer combinations are also frequently utilized as commercial freight vehicles. The multi-trailer articulated vehicle becomes the less preferable method of freight transportation as a result of handling challenges and instability effects when compared to the tractor-semitrailer. So, a tractor-semitrailer combination, a commonly utilized articulated vehicle, is discussed in this paper.

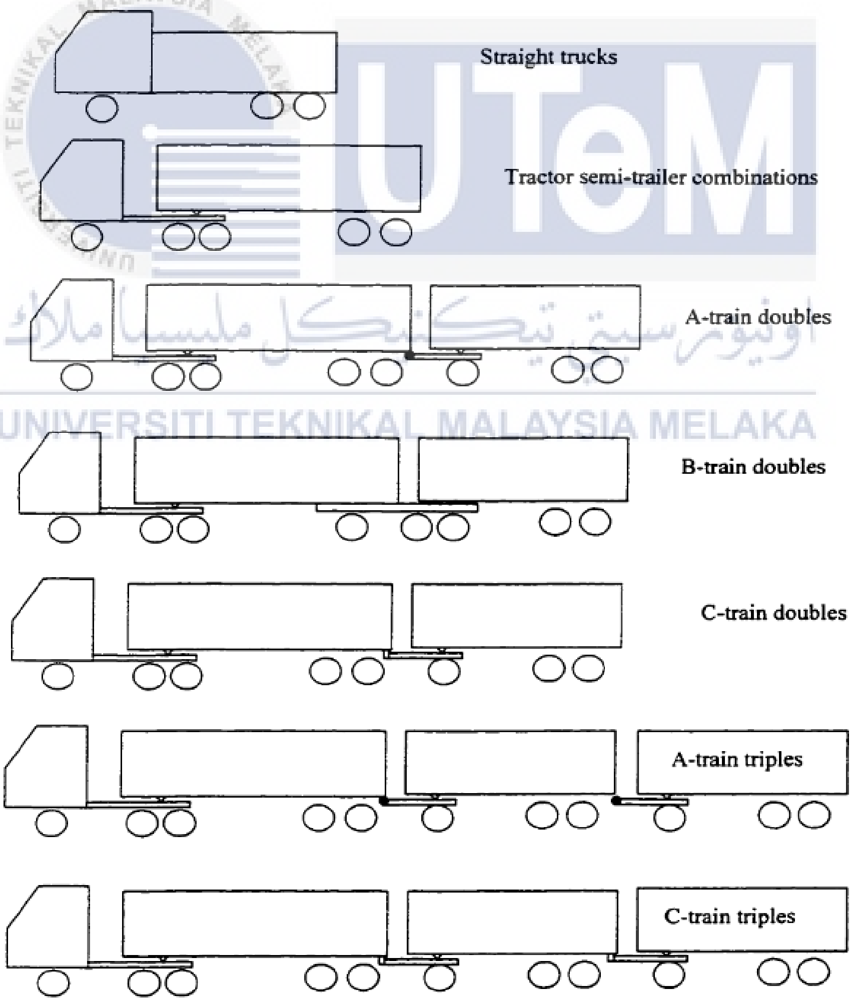


Figure 2-6 - Schematics of seven generic families of heavy freight vehicles

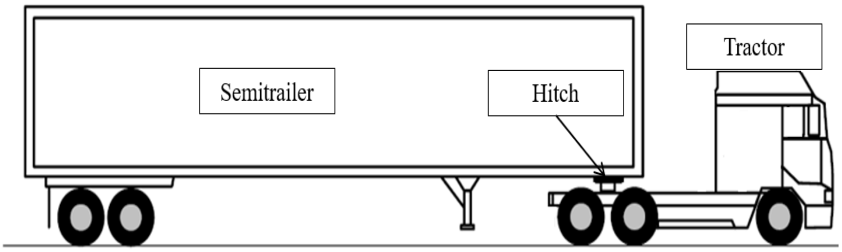


Figure 2-7 - Tractor-semitrailer combinations

There were descriptions of the many categories of heavy goods vehicles and hitch designs. The goods transportation company has established cost-effectiveness and manoeuvrability as crucial requirements. To avoid any traffic accidents involving the driver, other drivers, and cargo, it is imperative to prioritise the improvement of vehicle safety features. The summary of commercial goods vehicle classification is shown in Table 2.1.

Vehicle Types	Strength	Weakness	Comments
Single Utility Truck	Easy to manoeuvre due to single unit	Less goods	Most suitable for inferior goods and limited space areas
Multi-trailer Articulated Vehicle	Large goods and cost-effective	Handling difficulty and instability due to many articulated	Most suitable in freight large goods and limited area
Tractor-semitrailer	Large goods and cost-effective Easy to manoeuvre	Lower goods compared to multi-trailer articulated vehicle	Suitable for large-good and areas

Table 2-1 - Summary of classification of commercial freight vehicles

2.4 Vehicle Blind Spot

It might be difficult to see other vehicles or objects when the driver's direct line of sight is obscured in an area that is known as a vehicle blind spot. These blind spots, which are often found at the sides and back of the car, can be very dangerous when turning, merging, or changing lanes. Accidents and collisions may result from failing to adequately check for blind areas. Blind spot detection systems, mirror modifications, and other technologies have been developed to help drivers discover and navigate these concealed areas since it is crucial to solve this safety risk. Some work is being done to lessen or entirely eliminate the car's blind spots in order to eliminate these flaws that cause accidents among road users with heavy vehicles. An automobile's blind spot is the region beyond its side and rear-view mirrors where the driver is unable to see other vehicles. Although the blind spots in most passenger automobiles are positioned at a 45-degree angle behind the driver, the blind spots in large commercial trucks are frequently longer and wider.

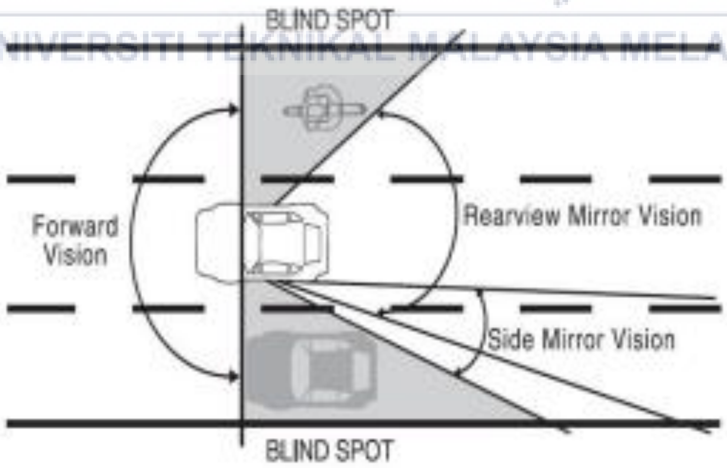


Figure 2-8 - Blind Spot Definition(Beresnev et al., 2018)

The regions towards the rear of the car on both sides that are most frequently referred to be blind spots are the rear quarter blind spots. These blind spots may prevent drivers from seeing vehicles in the adjacent lanes of the road if they are simply utilizing their car's mirrors. The regions that are too low to see behind and in front of a vehicle are also referred to as blind spots. Additionally, regions to the left or right can develop blind patches when side vision is impaired (Beresnev et al., 2018).

Blind spots may also be present in front of and behind the truck, depending on its size and shape. Most drivers take their time passing trucks, not realizing that by staying in the truck driver's blind spot, they are putting themselves in danger. Unfortunately, a truck driver cannot be held responsible if they change lanes or changeover without seeing another vehicle, which results in a truck crash.

2.4.1 Type of Blind Spot Accidents

Due to their size, heavy vehicles have operational limitations such wide blind spots, protracted stopping distances, and constrained agility, which necessitates that other vehicles pay additional attention to safety. The participation of heavy vehicles in fatal accidents has increased the need to better understand how this vehicle type affects other road users. As a result, this study aims to assess typical heavy vehicles collisions and the associated factors that contributed to other road users' deaths.

The size and weight of these heavy goods vehicles greatly increase the severity of their collisions with other vehicles involved in traffic accidents. Due to heavy vehicles regular 10 drive more slowly than other cars, the difference in speed due to their weight could result in rear-end incidents when a sudden braking happen.

The Federal Motor Carrier Safety Administration (FMCSA) refers to the blind spots of large trucks as "no zones" and they are much wider: 20 feet directly in front of the large truck, 30 feet directly behind it, two lanes to its right, and one lane to its left. Those who are caught in this wide area of reduced visibility are in grave risk.

By monitoring the blindspot area that include two feet in front of the truck between window and ground, directly to the left and right of the truck off-centre, and directly behind the truck up to nine feet away.

Figure 2-9 - Blind spot of a heavy vehicle

Any vehicle moving through one of the above-depicted red zones will be in the truck's blind spot. Additionally, keep in mind that whenever you drive past a truck, you always pass through one of those red zones. They cannot be avoided. To avoid any potential mishaps, you should aim to get through them as soon as you can.

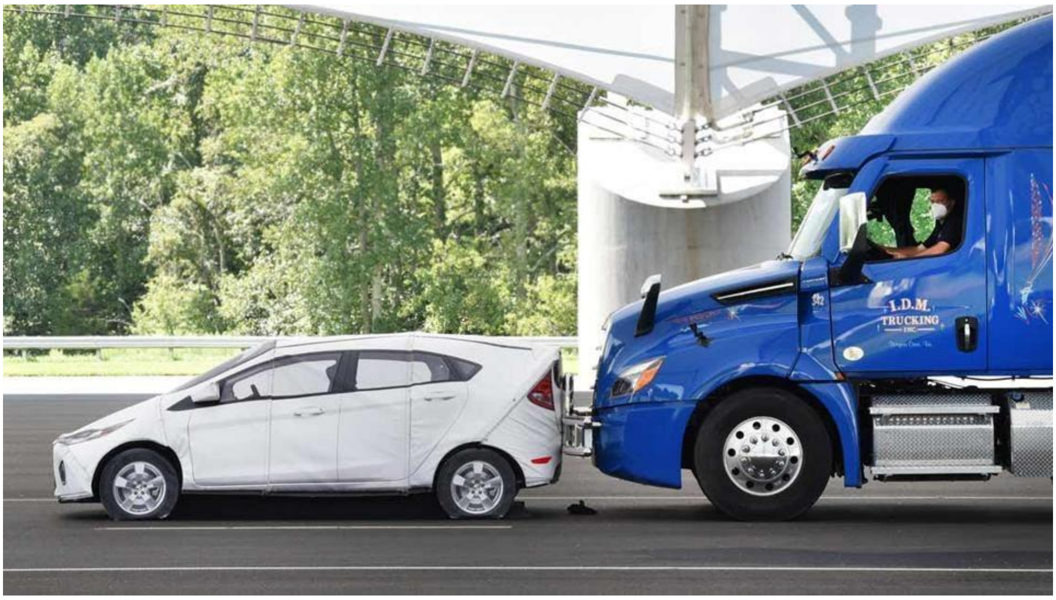


Figure 2-10 - Front collision on blindspot region

The car's front shares the same characteristics. American trucks often have a long hood, and the driver sits roughly 10 feet from the ground, in contrast to European trucks, which typically have flat front ends, like a bus. This makes passing a truck and merging in front of them exceedingly risky because truckers can't see the first 20 feet in front of their vehicle.

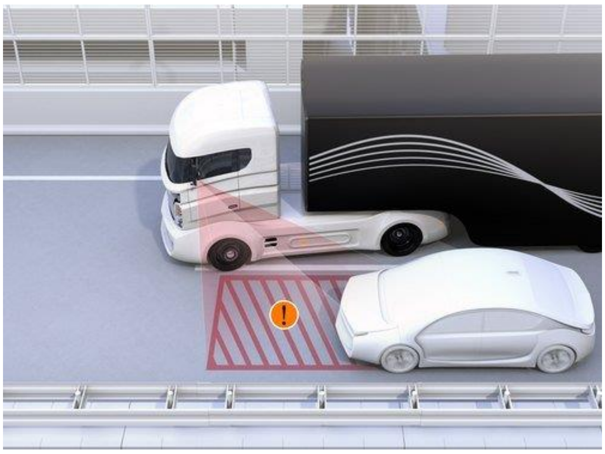


Figure 2-11 - Side collision on blindspot region

The side-view mirrors are positioned so that you can see far behind the car. That means even if cars next to them may view their mirrors, truckers often are unable to see what is right beneath the driver-side window. The no-zone on the passenger-side mirror is even larger and concave, like a bubble. Typically, a truck driver cannot see anything in the two lanes directly to their right. Because of this, passing trucks on the right is particularly risky because the trucker could not notice someone is there until they try to merge.

Figure 2-12 - Rear end collision on blindspot region

When a vehicle follow to close behind a heavy vehicle truck, the truck driver most likely be blind if the car is on the no zone that are in specified range of area. Average no zone size for an average truck was 30 feet due to not having a rearview mirror or backup cameras.

In a study conducted by the Federal Motor Carrier Safety and Administration, it was found that 20 000 truck accidents occurs each year as a result of due to blind spots or because the truck driver did not sufficiently examine the area before driving.

Figure 2-13 - Lane changing accident due to blind spot

Accident in lane changing often occur due to driver failed to monitor blindspot area. This often happen in traffic jams, on high occupant roadway where other small vehicle crowding especially cyclist and motorcyclist(Pokorny et al., 2017) the heavy vehicle truck making it difficult for the truck to make judgement on their measurement of blindspot during lane changing. For this project we covering all the blindspot area that includes for semi-trailer type of heavy vehicle.

2.4.2 Blind Spot Region

In Malaysia, there are three primary categories of HGVs: rigid lorries (two or more axles and more than 2.5 tonnes of permitted gross weight), trailer (articulated lorries) and small lorry or pick-up (two axles and less than 2.5 tonnes of legal gross weight). However the most seen on the road and have the highest posibilities for involved in road accident were trailer due to their size (Consultation Paper, 2006). The majority of deadly incidents occur as a result of truck drivers' poor vision. To address this issue, some nations enact laws requiring the use of either cameras or mirrors to give drivers a complete view of the area around their vehicles. The biggest drawback of mirrors is that different regions around the truck are amplified differently. Because of this, items close to the vehicle only cover a small portion of the mirror surface, making them difficult to see, especially when the driver turns right and must simultaneously check up to six mirrors. (Pyykonen et al., 2015)

Figure 2-14 - Blind spot region (red) of the truck-trailer combination shown on the ground plane. The width is about 2 m. A large blind spot region arises in front of the vehicle as well as on the passenger's side.

In this case, a single-track model of the vehicle is used to do this. The kink angle obtained by the single-track model is compared to the kink angle provided by a sensor positioned at the connection joining the truck and trailer to demonstrate the model's correctness. Due to the criteria and costs of the automotive industry, such a sensor cannot be used in vehicles that are produced in large quantities.

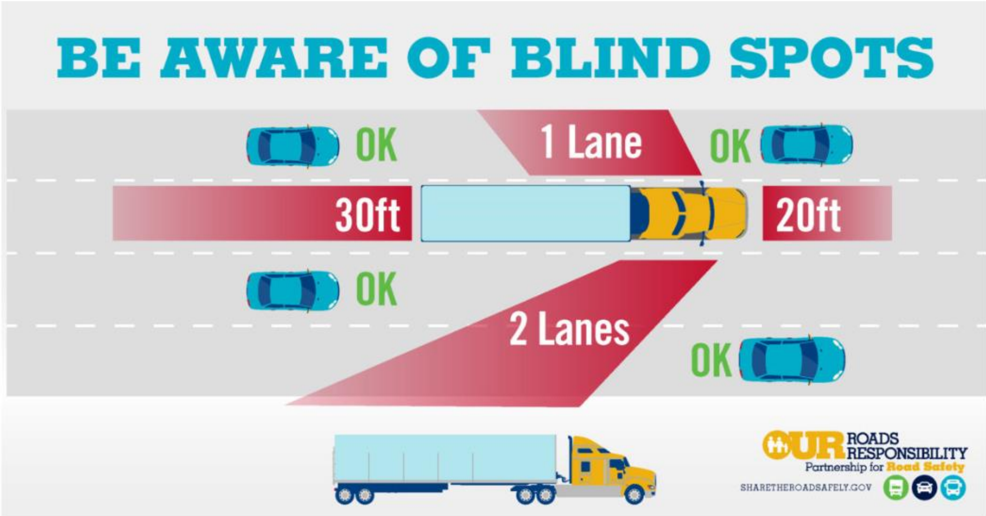


Figure 2-15 - shows "No-Zones".

Semi-truck blind zones also known as “no-zones”, were identified at the left side, under the cab mirror, right side under the cab mirror exerting out, in front of the truck cab at least 20 feet and behind the trailer at least 30 feet. However, in knowing when you were out from the blind spot region, you must be able to see the truck driver or else the truck driver not able to see you which can cause hazard on the road.

2.4.3 Sensor positioning

Sensor positioning is crucial for an optimum detection for blind spot system due to its placement of sensor to detect an object passby. According (Beresnev et al., 2018) the area surrounding the front windshield's A-pillars that obstructs the driver's view of objects or pedestrians is referred to as the vehicle A-pillar blind spot. The A-pillars are the horizontal braces that link the windscreen to the car's body on either side. They provide the car its structural strength but can also lead to blind spots.

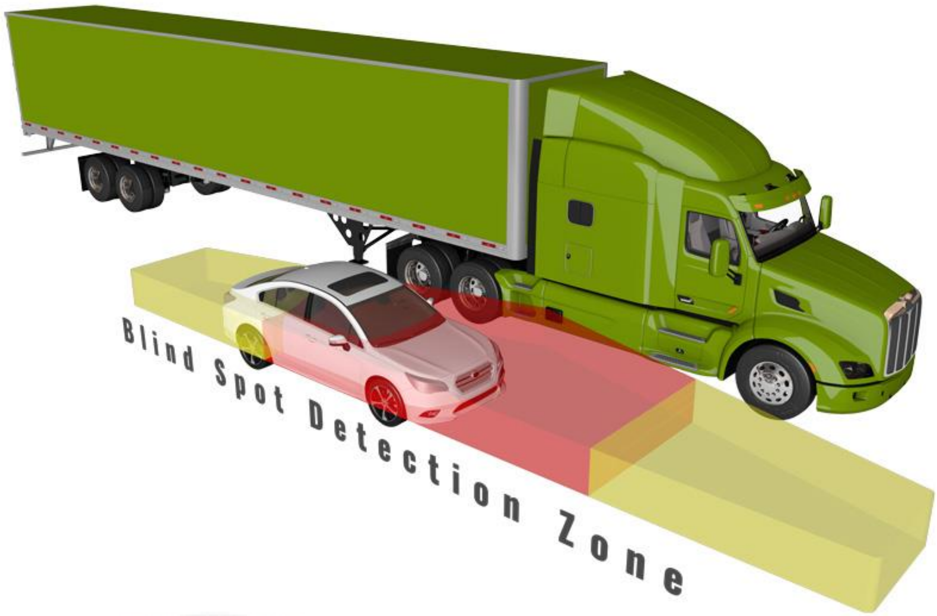


Figure 2-16 - Blind Spot Detection Zone

To minimise annoyance alarms, it ignores stationary objects like guardrails when in highway mode but warns drivers of cars in the side blind zones. The blind-spot detector is positioned to be a key component of the upcoming side turn assist applications in slow-speed mode, which are specifically designed to lower the frequency of collisions with pedestrians and cyclists in urban contexts.

Numerous researchers have looked into the collision risk level. Vehicle trajectory, speed, and collision position were discovered to be affecting variables. The turning speed has a direct impact on the trajectory of the vehicle. Changes in turning radius, particularly for large vehicles, have an impact on the size of the blind zone caused by inner wheel discrepancy. A limited turning radius results in a significant inner wheel difference and raises the chance of an accident

The position of the collision is also thought to have an impact on the sensor positioning to monitor the area possible risk and factor that contribute to accidents.

Figure 2-17 - Camera video attach at the bracket of side door

The greater viewing angle provided by cameras over external side mirrors allows the driver to accurately analyse the traffic situation (Beresnev et al., 2018).

According to R. P. Mahapatra (Beresnev et al., 2018) ultra sonic sensor based blind spot accident prevention system, it uses radio frequency waves as a means of proximity detection. It consists of five components: a front sensor, a side sensor on each side, a side sensor on the right, an LED metre, and an Audible alarm.

The front sensor is mostly useful for identifying seasonal black areas (such as front-light failure in cases of fog). By transmitting radio waves, this sensor can identify the presence of any object and, in the event of momentary blind areas, can alert the user to impending threats.

Basically, a metal strip that runs the length of the back of the car, from left to right, covering the entire back region, is used. On the extreme left and right sides of that strip, respectively, are left and right side sensors.

This display metre really has LEDs that light up when a close creature is detected, signalling a potential concern.These LEDs will quit glowing after the area has been cleared.As seen in figure 2.1, this LED metre will be mounted in front (Beresnev et al., 2018).

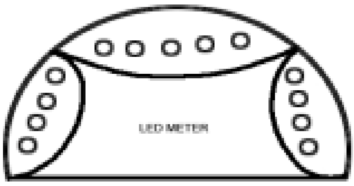


Figure 2-18 - LED Meter

Figure 2.2 illustrates how a blind spot sensor on the left side detects an object or entity since it can be seen that the LEDs on that side are shining.

Figure 2-19 - Left Side Sensor LED Meter

Figure 2.3 illustrates right-side sensor detection of a blind area; as can be seen, the right-side LEDs are lighting, indicating the presence of an object or other entity.

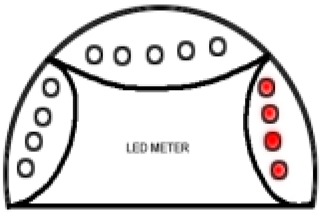


Figure 2-20 - Right Side Sensor LED Meter

Figure 2.4 shows how the front sensor detects a brief blind zone since it can be seen that the LEDs on the top (front) side are shining, which indicates the presence of an object or other item.

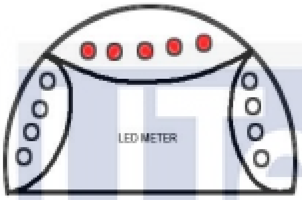


Figure 2-21 - Front Side Sensor LED Meter

An audio alarm is activated to communicate the identification of an entity as soon as the detection of an entity is confirmed and the LEDs on the LED metre begin to illuminate. When an LED or display malfunctions, this loud alarm is quite helpful. The sensor used in this part was positioned as depicted in figure 2.5.

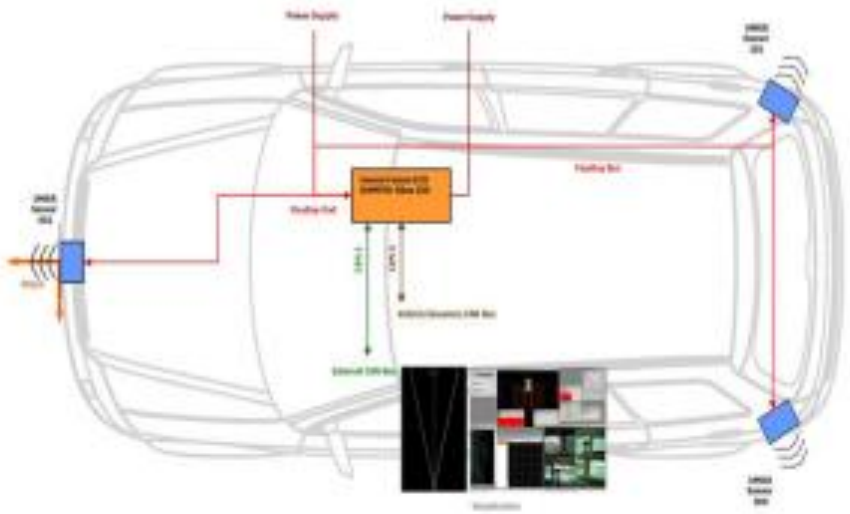


Figure 2-22 - Sensor Placement on a car

However for a heavy vehicle comes with extra length and bigger size form a larger paramater area that has to considered for sensor placement.

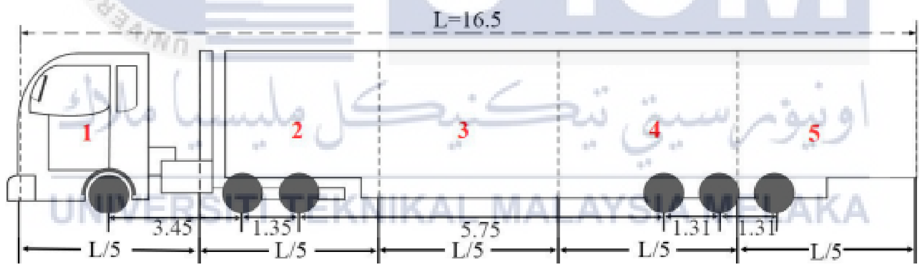


Figure 2-23 - Parameters of the test vehicle (Unit: meters). (Q. Wang et al., 2022)

As illustrated in Figure 1, the semitrailer was separated into 5 evenly spaced regions, 1 through 5, indicating the 5 distinct collision positions, in order to better understand the collision situation. Positions of each part divided received data in knowing the behaviour of the test vehicle during turn and in parking lot position. Blind zone range determine within the steering angle, the more the turn the bigger the blind zone achieve from static to dynamic.

The driver maintained the highest steering wheel turning angle throughout right-turn operation to achieve the greatest blind zone range(Q. Wang et al., 2022).

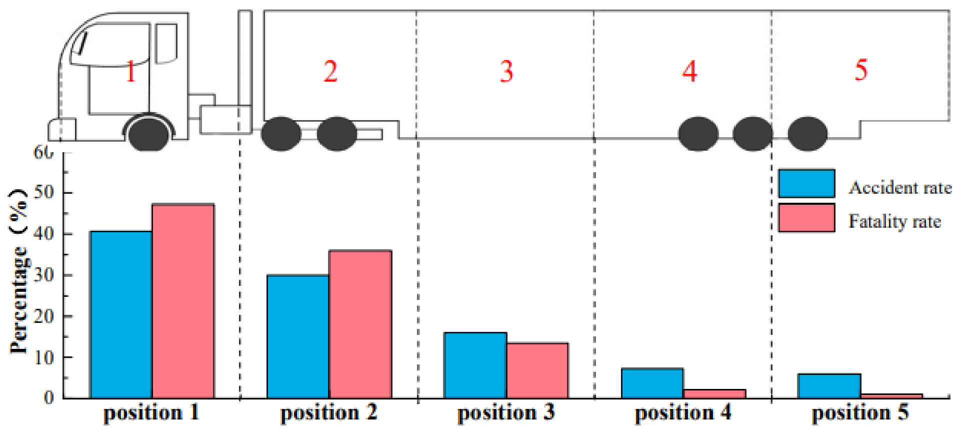
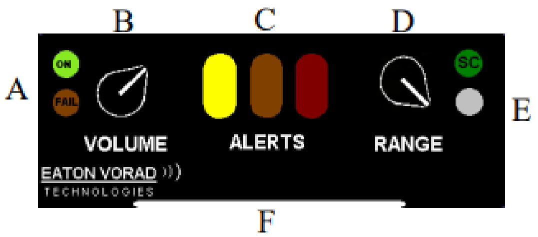


Figure 2-24 - Proportion and accident severity in each divided semitrailer truck

Table 3 displays the accident data that was gathered during the PC-CRASH simulation test with five crash positions. Notably, the simulation outcomes once more show a strong correlation between the crash severity and the collision position. The chance of a rider suffering a significant secondary injury from being crushed by the tyres behind increases with forward position since it is more likely to result in a larger inner wheel difference blind zone.

2.5 Blind Spot Detector Devices

Some solution implemented in form of devices to solve the blind spot area problem among the heavy vehicles. According to Volvo Trucks, all 100 Free On Truck, FOT vehicles were equipped with the commercially available Eaton VORAD® EVT 300 CWS, which provides collision warning. A forward-facing, front-end mounted radar antenna is used by the system to send and receive radar signals. The host vehicle's distance and relative speed from objects in front are calculated by the Central Processing Unit, CPU using data from the antenna. When other vehicles are within specified distances or closing periods, the system offers auditory and visual alerts on the display unit (see Figure 2-25 below) to advise drivers of potentially dangerous circumstances. This offers drivers more time to respond and, ideally, perform avoidance manoeuvres to prevent a rear-end crash (Lehmer et al., 2007).



A: System operation indicators
B: Volume control knob & on/off switch
C: Visual alert indicators & speaker
D: Range setting knob
E: Light sensor
F: Driver ID card slot

Figure 2-25 - Eaton VORAD® Display Unit(Lehmer et al., 2007)

Another stereo based vision blind spot detection system consists of two spheric lens cameras to obtain a broad field of view while significantly distorting the images. Right beneath the front window, they are situated, as and are randomly positioned in figure 4. In particular, the cameras only capture the driver's blind spot area(Bertozzi et al., 2006).

Figure 2-26 - Position for stero based vision blind spot detection system

Figure 2-27 - (a) left source image undistorted (c) distorted image

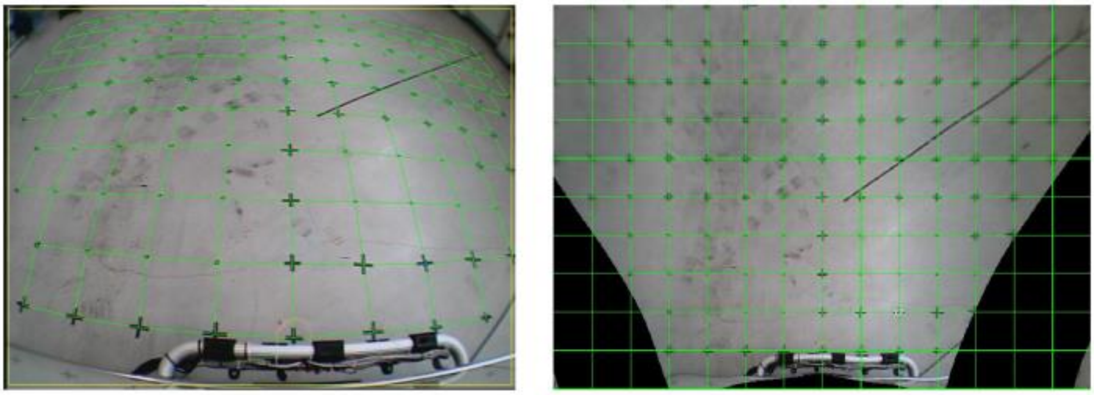


Figure 2-28 - Original and undistorted image of the grid

The stereo vision devices have an advantage to detect any object by undistorted the camera vision to identify objects in front of the truck and covering the blind spot area in the front (Bertozzi et al., 2006).

2.6 Implementation and testing

For implementation and testing, Software-In-the-Loop (SIL) and stand-alone device were the two methods employed for implementation and testing. The testing of generated solutions through simulation of real-world conditions is made possible by the usage of Software-In-the-Loop (SIL) solutions. This reduces the requirement for testing actual prototypes and increases development and quality control.

2.6.1 Software In the Loop (SIL)

The code used to monitor and fix system-level problems, like code generation validation, was subjected to unit tests. Early in the software development process, it is feasible to simulate software in the loop, or SIL. It makes it possible to run tests before hardware is available, which enables the discovery of errors. (Ben Ayed et al., 2017). Using software-in-the-loop modelling has the benefit of enabling pre-production design testing.

Within the same vehicle, the dynamics are frequently replicated based on its features. Determining the general behaviours and features of a design can be done very successfully and economically with this method. In contrast, the model type and supporting data have a significant influence on the correctness of the findings drawn from comprehensive computer models. (O'Hara, 2005)

2.6.2 Stand-alone Devices

Standalone devices are electronic gadgets that function independently, without needing to be connected to a central system or another device. Its function as a self-contained unit that perform specific tasks. The area beside and off-set to the rear of the moving car on both sides that is not visible through the driver's line of sight or mirrors is known as the blind spot. The BSD technology keeps an eye on the vehicle's blind spot area using radar, cameras, or ultrasonic technologies. A warning signal is sent out if anything moving is seen inside the designated area. (M. H. Wang & Wei, 2016)

2.6.3 Implementation and testing in simulation

The driving simulator is a graphical device that gives the driver the impression of operating a vehicle on an interstate. Driving a real car and using a simulator differ in a key ways, though. The way the mirrors work is different from how they would in a real car. The driver's ability to see their surroundings is compromised. There isn't a brake pedal either. The interior of a normal car is shown to the driver, complete with a digital speedometer and an amber blind spot light. (Racine et al., 2010)

Figure 2-29 - Screen shot of driving simulator. The driver interacts with the scene from within the driver's seat of the simulated vehicle. (Racine et al., 2010)

Many prior works have focused on either developing realistic simulation environments with more robust training or on more cautious exploration within the real world. While these methods improve robustness and safety, they do not address scenarios in which the agent has a flawed representation that prevents it from learning calibrated uncertainty estimates. (Ramakrishnan et al., 2020) Interface to the simulation is made possible through a custom Telemetry SDK plugin installed in the game. The plugin is set up to send out TCP packets containing the stateful data of the truck and car, such as the following: position and orientation; linear and angular velocities; linear and angular accelerations; engine gear and RPM; effective braking; and throttle and steering values. A specially created ROS wrapper parses the packets and transforms them into standardised ROS messages. The world's information, such as lanes and construction zones, as well as details about other cars on the road, are not provided by the simulator. (Darwesh et al., 2020)

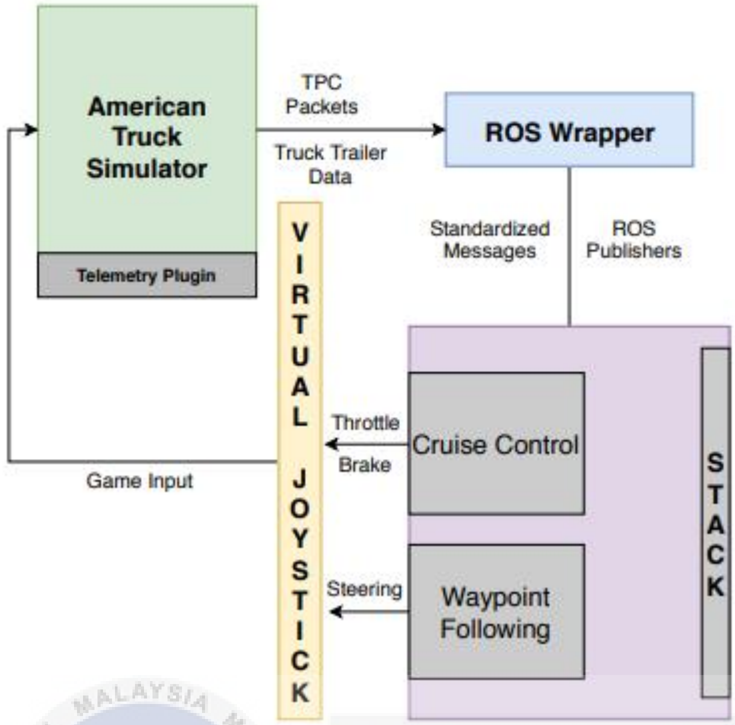


Figure 2-30 - American Truck Simulator Communication Flow (Darwesh et al., 2020)

CHAPTER 3

METHODOLOGY

3.1 Introduction

In general, blind spots occur when a vehicle position enters blind zones of heavy vehicle also known as no zones. Blind spots can also lead to fatal accidents involving road occupants especially involving heavy vehicles when the driver did not aware of the situation, same as the vehicle that drive around the area circumference of the heavy vehicle. Once the vehicle blind spot phase commenced, there is insufficient time for the actuators to react effectively, especially in serious situations. In avoiding any catastrophic blind spot accident to occurs, it is important to be able to evaluate the blind spot detection and determine the blind spot detection sensor position to achieve an adequate amount of time ahead of time.

Therefore, to provide a compromised solution to these two-conflicting requirements, an integrated blind spot warning device is to be designed and manufactured to overcome this possible blind spot accident concern. Its purpose is to determine the optimum position for sensor and provide the driver with an early warning as another vehicle entered the heavy vehicle blind spot. It is built with MATLAB Simulink to forecast what would happen if some external inputs were applied to it.

3.2 Project Flowchart Process

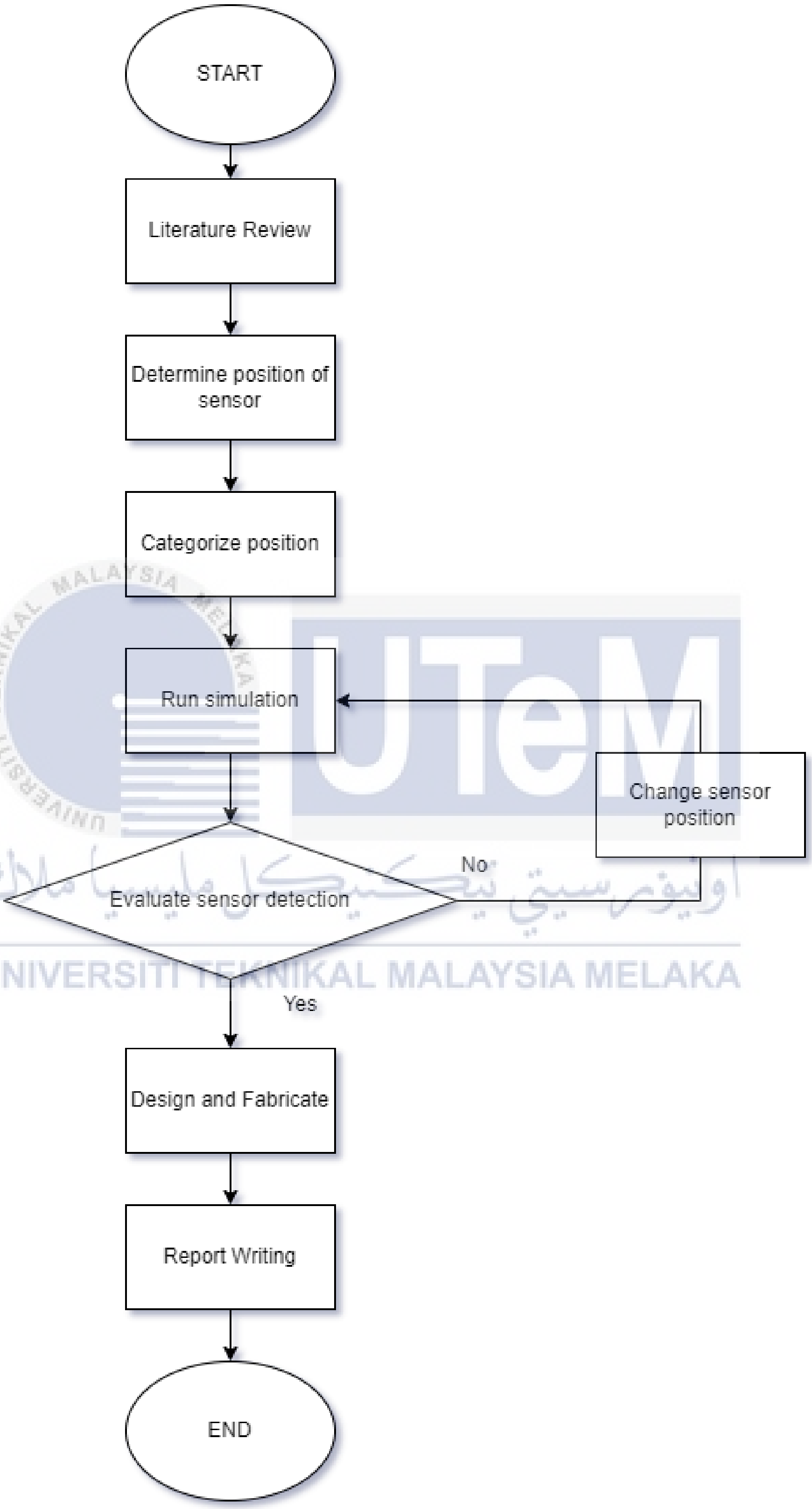


Figure 3-1 - Project Flowchart Process

3.3 Software In the Loop (SIL)

The algorithm input will be applied to software in the loop using the TruckSim driving simulator. Vehicle type, speed, position and scenario data must be entered into the TruckSim driving simulator programme. Following that, the TruckSim driving simulator will create input in the form of vehicle pass by the blind zone from the left side of the truck. At the second block, these parameters will be used as input for the sensor detection. The algorithm for blind spot detection system will be used in the Matlab/Simulink software to generate the result data graph. This figure can be used to determine whether the vehicle sensor positioning is optimized. The Signal value is greater than or equal to one when the truck detect a passby vehicle. When the value is more than one, the speaker will sound a warning and the LED set will flash.

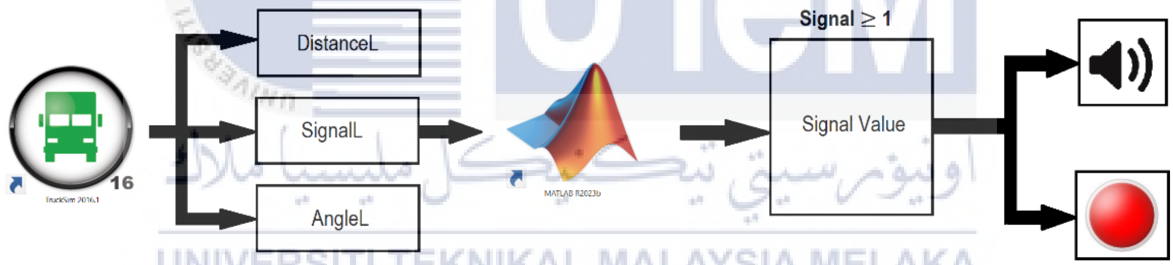


Figure 3-2 - Signal from Algorithms in Software in the Loop

3.4 Hardware In the Loop (HIL)

The software in use for designing and creating blind spot detection devices was TruckSim and MATLAB Simulink, from that we able to gain the detection region, position and length of the object position from the sensor, hence able to determine optimum sensor position for blind spot detection devices. The software allow to give input on the distance of an object from its initial position of the shortcut and enables us to run our simulation and display a warning through the simulation thus extracting this data and process in MATLAB Simulink to embed to creating a warning device that display warning to driver whenever an object pass the truck blind spot region. The drafting of the blind spot warning devices is dependent on needed dimension, as illustrated in flow chart below. Before applying the Arduino Due board, the designed collection of blok models created for the signal detection of blindspot sensor. The warning device will receive the signal from sensor and the LED and buzzer will trigger upon the object entered the sensor region. (Sarhadi & Yousefpour, 2015)

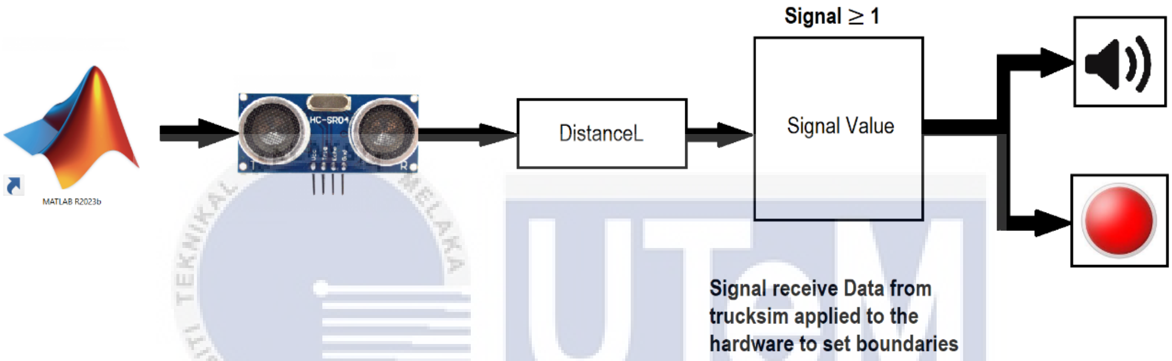


Figure 3-3 - Signal from trucksim used in Hardware in the Loop

3.4.1 Parameters

The parameter included a procedure of truck moving at a constant speed with 110km/h in 20s with an passby vehicle with speed of 33m/s pass along left side of the truck blindspot the passenger side. It was found that blind spot area on the left side of the car was larger compared to the right side, while BSZ angle of the left side was smaller than the right side. This might due to the design of the side mirror and its effects on the driver's viewing angle and field of view. (Hashim et al., 2021) Therefore, we observe 3 different position at prime mover and trailer to obtain most optimum sensor position for early warning.

3.4.1.1 Heavy vehicle

The parameter for this thesis is used from the TruckSim simulation 3A Cab Over Sprung mass.

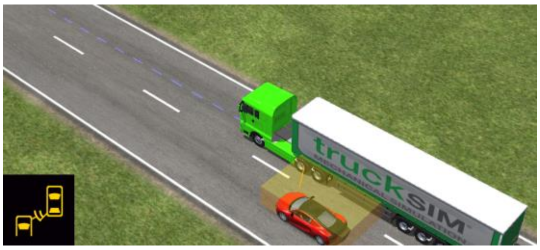
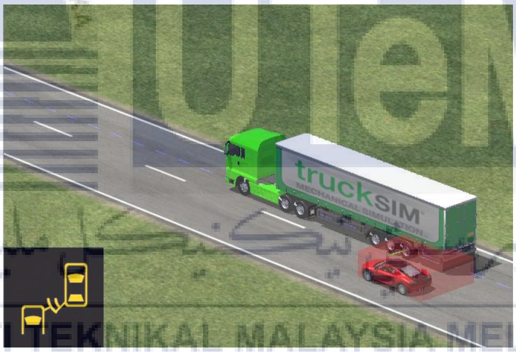
Parameter	Value
Length, *l*	5250 mm
Width, *t*	2438 mm
Height, h	3200 mm

Table 3-1 - Parameter for Truck

3.5 Simulation Setting

The parameter for this thesis is used from the TruckSim simulation.

Location	Position	Position of sensor detection from main body	Coordinates of sensor in sprung-mass coordinate system (mm)
Prime Mover	1		X: 1500 Y: 800 Z:500

	2		X: -10500 Y: 800 Z: 500
	3		X: -3500 Y: 800 Z: 500
Trailer	1		X: -9000 Y: 800 Z: 500
	2		X: -10500 Y: 800 Z:500

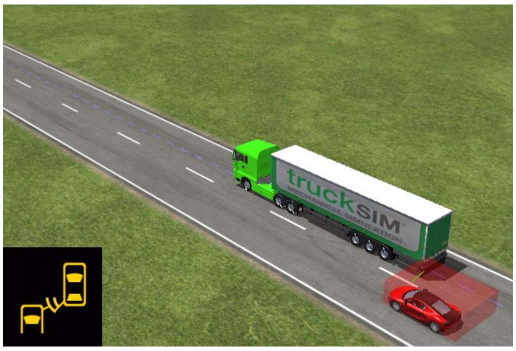
	3		X: -12500 Y: 800 Z: 500

Table 3-2 Sensor positioning parameter

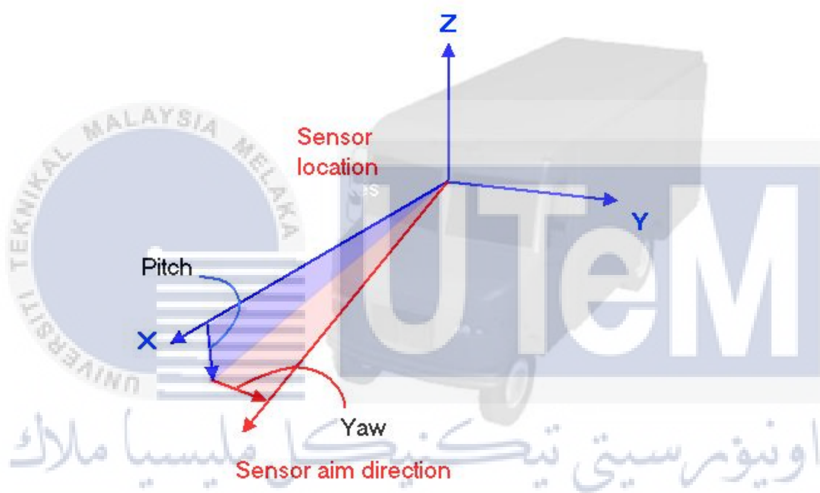


Figure 3-4 - Sensor point of origin and aim axis directions

3.5.1 MATLAB

This project requires the use of MATLAB to be able to plot and export graph of sensor position to identify the optimum position of sensor. MATLAB is a programming languange and interactive environment for mathematical computing for analyzing the data gathered. (Kholkhujaev et al., 2020)

3.5.2 Simulink

To delve into the dynamic heart of complex systems, we apply software in the loop into the simulink. Block diagram built with an add-on package that support Arduino hardware and sensor is the need to transfer input data gathered from TruckSim simulation into the block diagram of blind spot detection system device.

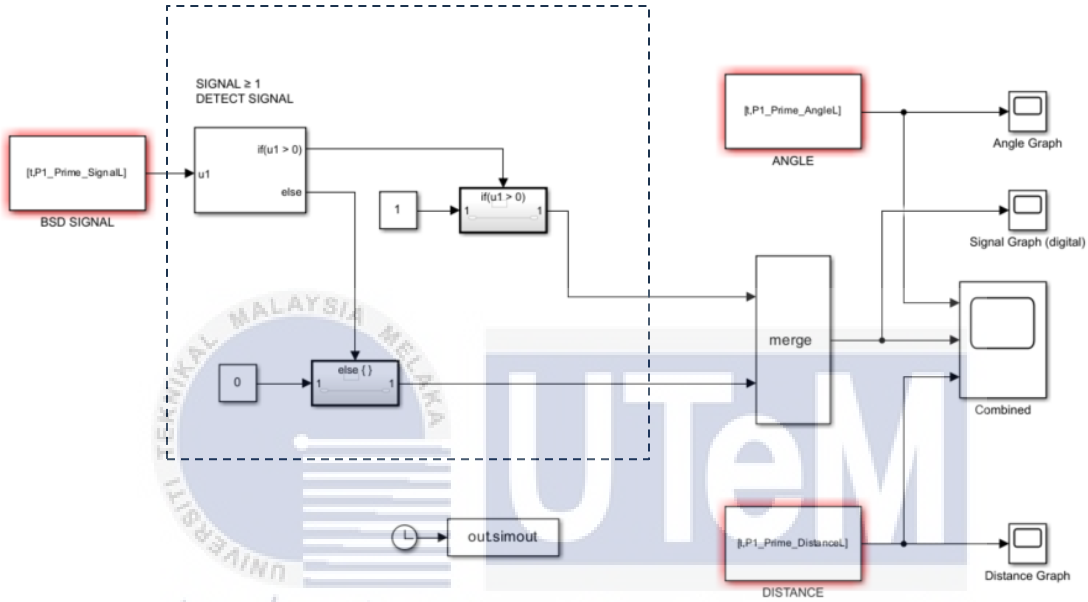


Figure 3-5 - Simulink Block Diagram for Sensor detection SIL

The simulink will receive data from TruckSim being uploaded to MATLAB workspace. The signal receive is in digital signal consist of 0 and 1, hence it being filtered by if-subsystem for determining the signal when trigger 1, object is in blind spot region. When signal trigger 0, null displayed. Therefore we use this sensor signal to determine the distance and angle of object detection within detection range by merging the signal, distance, angle graph.

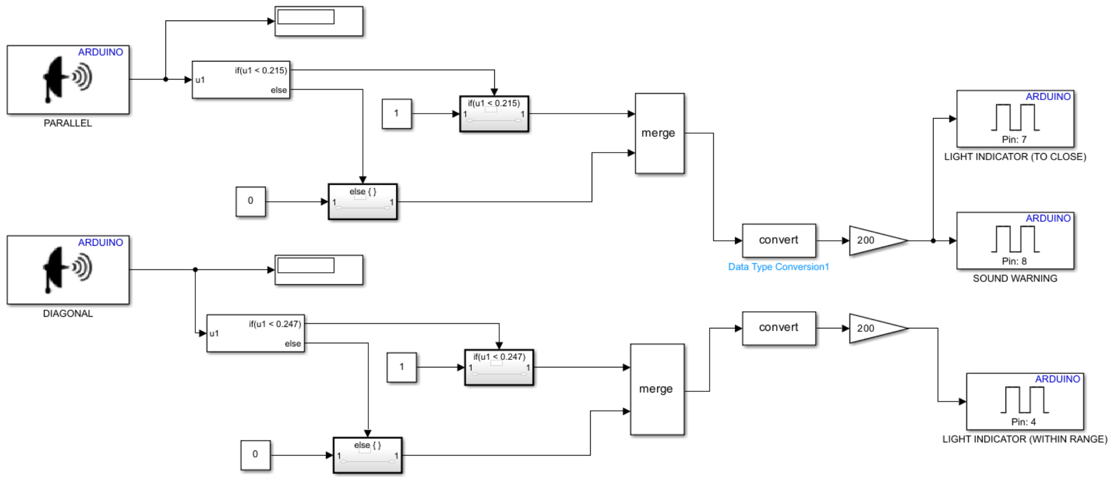


Figure 3-6 - Simulink Block Model for Sensor detection HIL

The Block models are included in MATLAB/Simulink arduino package were used. The setup for the hardware was including two pair of ultrasonic sensor wih parallel and diagonal to the parallel in achieving the maximum blindspot detection. As the scale of the truck is 1:20 so we need to scale down the data to match the RC truck specifications and thus display the data on most optimum position for heavy vehicle blind spot detection system.

3.6 Equipment

Some equipment must be used for this project including electronics. However, before buying the hardware, we can save cost by designing and simulating the circuit inside TinkerCad software. Using TinkerCad by Autodesk software, clearly design a blind spot detection devices and obtain an ouput for sensor detection and the distances of object sense by the sensor before making it a prototype using real sensor and actuator.

3.6.1 Arduino Due

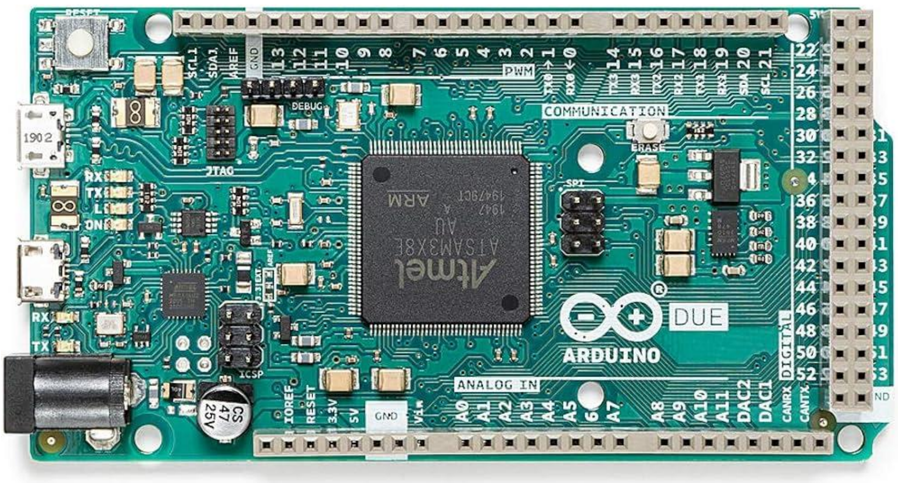


Figure 3-7 - Arduino Due microcontroller

The Arduino Due is the ideal board for those who want to advance dive in about larger project and software implementation. The renowned AT91SAM3X8E and the 512KB Flash with 100KB SRAM are both included in this adaptable microcontroller to withstand more complex block as the bigger size of memory. Your introduction to the world of Arduino will be excellent thanks to this board (Manual, 2022). Arduino Due react as a microcontroller for the blind spot detection devices, processing all the input and interpret into an output that able to detect object in or pass through blind spot region and give warning to vehicle driver.

3.6.2 Ultrasonic sensor

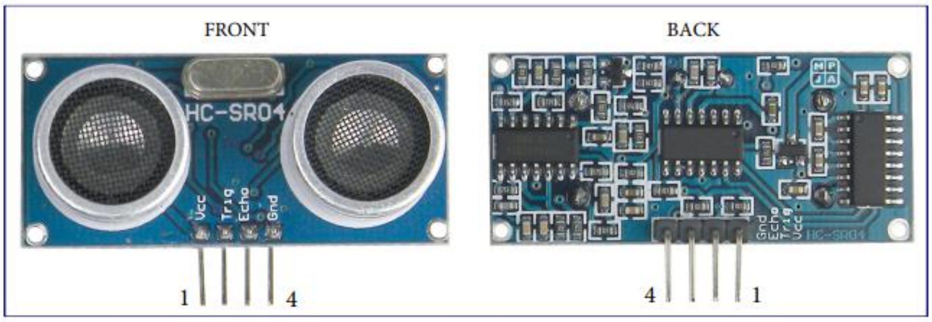


Figure 3-8 - Ultrasonic Sensor HC-SR04

8 bursts of a directed 40KHz ultrasonic wave are released by the transmitter when triggered, setting off a timer. Ultrasonic pulses go outward until they come into contact with something, at which point the wave is reflected back towards the source. The wave would be reflected, and the ultrasonic receiver would find it and stop the stop timer. The ultrasonic explosion travels through the air at a speed of 340 m/sec.

The distance between the item and transmitter can be determined based on how many times the timer counts. The time, rate, and distance measurement formula, also known as the TRD measurement formula, is written as D = C X T. D stands for the measured distance, R for the propagation velocity (Rate) in air (speed of sound), and T for time. T is divided by 2 in this application because it takes twice as long to travel from the transmitter to the item and back to the receiver.

Ultrasonic sensor transmit wave to reflect it back and its from a near object in its range to receive information in terms of waveform. In case of this project, its role is to detect any object from its fixed position of no zones area to receive initial data for detection of any vehicle and measure the length in between.

3.6.3 Piezo buzzer

Figure 3-9 - Buzzer/ Piezo

Piezo active buzzers that are connected directly to a DC power source have the advantages of high sound pressure, great sensitivity, low power consumption (usually 20 to 100 ma), good dependability, and no circuitry.It is mostly utilised in security, air conditioning, refrigerators, instruments, reverse radar, microwave ovens, printers, copiers, alarms, toys, automobile electronics, telephones, timers, audio equipment, vehicles, supermarket gates, and other electronic devices.

Piezzo buzzer used after receive signal from ultrasonic sensor that an object has been detected and to driver for intial warning so that the driver can react ahead of a time of time. Received signal from ultrasonic sensor into the microcontroller and produces a signal to be transmit signal to the buzzer to actuate the sound.

3.6.4 Jumper

Figure 3-10 - Jumper wire

Jumper wires has type such as a female-female, male-male, male-female for connect to breadboard. Increase the connection density of both components and jump wires on a breadboard without worrying about short circuits thanks to the part layout and ease of insertion. To distinguish the various operating signals, the jump wires come in varied sizes and hues. It function as connector for our sensor and microcontroller in order the system would operate.

3.6.5 LED

Figure 3-11 - LED

Leveraging light-emitting diodes (LEDs) for their high efficiency and precise wavelength control. These compact, solid-state devices convert electrical energy directly into vibrant, narrow-band light, eliminating the need for filaments and minimizing heat generation. We will utilize their tunable color spectrums to manipulate the experimental environment, achieve targeted biostimulation, or monitor specific chemical reactions. The fast switching capabilities of LEDs enable precise timing of light pulses, while their compact size and low power consumption facilitate integration into miniaturized experimental setups.

3.7 Limitation of Proposed Methodology

In particular in Malaysia, heavy vehicles were the preferred mode of moving transportation for transporting goods or other items. This paper research is focusing on this kind of heavy truck because it is commonly used for transportation and can help prevent blind spot mishaps. It might not be possible or practical to run an actual test in this situation due to practical restrictions or limits. However, as a substitute strategy, we have used simulation methods. In a controlled virtual environment, simulation enables us to duplicate and simulate the conditions, behaviours, and interactions.

We can faithfully reproduce the essential elements of the system or process under study through simulation. This comprises elements like physical characteristics, environmental circumstances, and intricate interactions that take place in actual situations. We are able to thoroughly analyse and assess the system's performance, behaviour, and results thanks to simulation. However, our current findings on electronics board connectors were limited and we only get to produce data for initial result only using two ultrasonic sensor. In the future, the system will upgrade fulfilling the criteria of the blind spot detection system by adding two more ultrasonic sensor at the front and back for optimum detection.

Furthermore, compared to actual testing, simulation has a number of benefits. It enables us to investigate a variety of scenarios, factors, and variables that might be difficult or expensive to accomplish in a physical test. Additionally, simulation enables us to analyse the system's behaviour under unusual or severe circumstances that can be risky or challenging to recreate in actual studies.

We may take wise decisions, get insightful knowledge, and successfully optimise our system or process by using simulation methods using software to collect data and result. It enables us to get around the constraints of actual testing and deliver beneficial results quickly and affordably.

3.8 Setup on RC 1/20 scale Heavy Vehicle Semi-Trailer

Figure 3-12 - Car before entering Truck blind spot

Figure 3-13 - Car entering Truck blind spot

Figure 3-14 - Car In Truck blind spot

Figure 3-15 - Car out of Truck blind spot

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

According to ASEAN NCAP, assessment of a vehicles equipped with Blind Spot Detection are evaluated using a series of tests which refer to the ISO 17387 as Lane Change Decision Aid Systems (LCDAS). They are fundamentally intended to “warn the driver of the subject vehicle against potential collisions with vehicles to the side and/or rear of the subject vehicle, and moving in the same direction as the subject vehicle during lane change maneuvers” in which blind spot technology system could be used to avoid crashes. (Yahaya et al., 2019) This chapter presents the results and analysis on the development of blind spot detection for heavy vehicle. According to the TruckSim simulation software, we set the procedure and parameter of the truck moving at 110km/h with a passby car with speed og 33m/s will detected by the sensor mounted in 3 different position at the prime mover and 3 other different position at the trailer to measure the most optimum sensor position to give an early warning to the driver. This section discuss the related sensor signal, distance and angle detected for accquire the the best and sensor position to alert the driver and implement the data gathered into a RC 1/20 scale for result.

4.2 The Performance of Blind Spot Detection System.

In addition, the included procedure operation was guided by the blind spot region, No-Zones are danger areas around trucks and buses where crashes are more likely to occur. Some of these “No-Zones” are actual blind spots where your car “disappears” from the view of the truck or bus driver. (NHTSA, 2015) The driver side of field view was more bigger that passenger due to driver position, this mean the passenger side will be more unseen by the driver and need to be more aids to keep the driver alert.

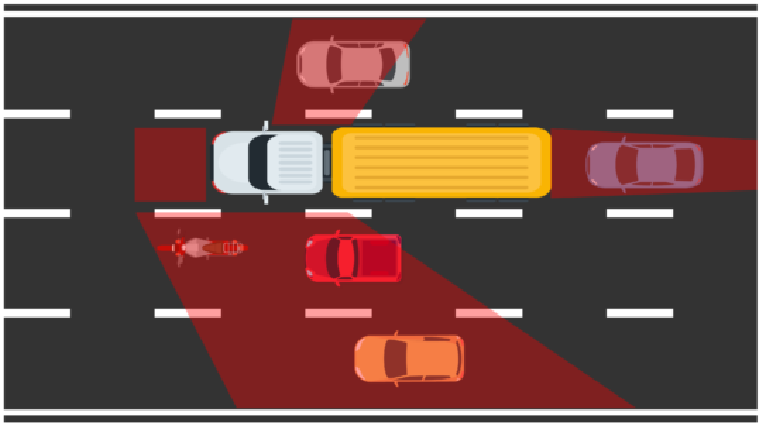


Figure 4-1 -Blind Spot region of RHS driver

A capability on evaluation for the blind spot detection procedure carried out in this study using TruckSim simulation and MATLAB/Simulink software. The result of the evaluation were used to determine the simulation sensor's capabilities. A stages of different position sensor technique being performed at a speed of truck 110km/h and a car pass by with 33m/s constant speed respectively. During the test the truck subjected to 2 different setup: Prime-mover, which the sensor being mounted in 3 different position: position 1 (1500,800,500), positon 2 (-10500,800,500) and position 3 (-3500,800,500) and another setup at trailer , position 1 (-9000,800,500), position 2 (-10500,800,500), position 3 (-12000,800,500). The simulation time period were set to 20 seconds and the result will be determine using the time taken of sensor detection based on signal detection. These configurations applied to the truck to determine the most optimum sensor position for early warning of the driver as the blind spot aid system for driver. The signal receive by the sensor in digital form (0,1) within time detection will be the benchmarks of the detected signal and result happen within the time period.

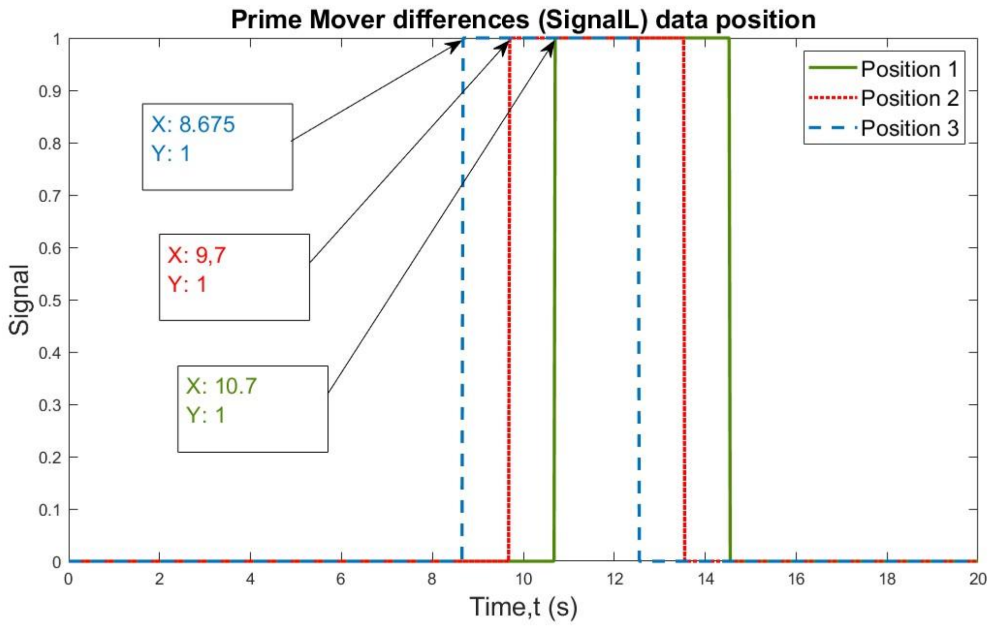


Figure 4-2 - Prime-mover sensor position signal graph

A comparison of prime-mover signal detection between position as shown in Figure 4-1. When the sensor detect upcoming vehicle approach within sensor range in blind spot, the signal will become 1 (ON), signal will turn off after 0 (OFF) when object come out within range. As shown in the position 3 has the fastest time detection compared to position 2 and 1. This is due to the placement of the sensor is closer to the rear axle making it crucial to detect since the blind spot of most right hand side driver is at that area. (Suriani et al., 2019)

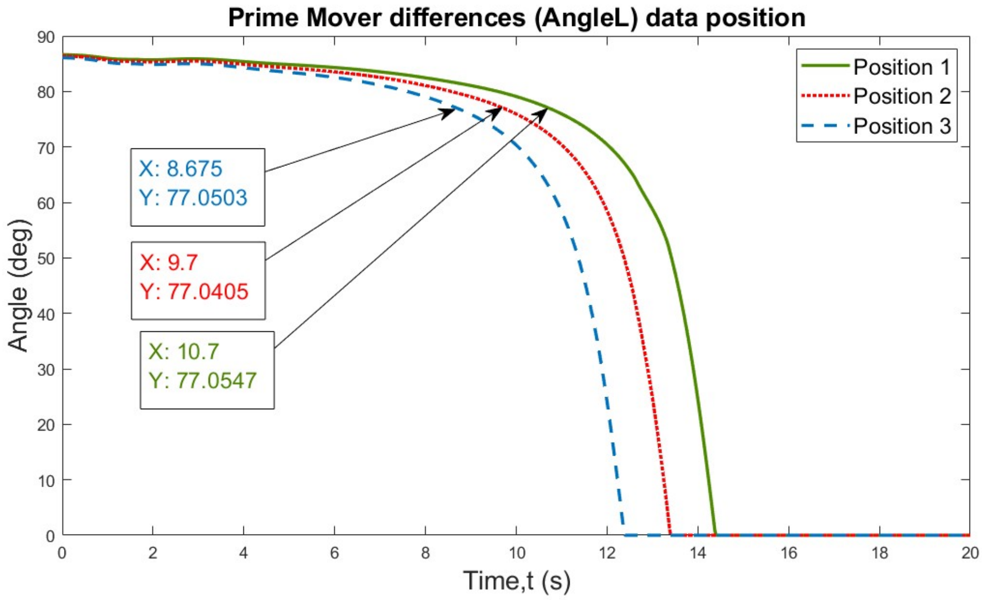


Figure 4-3 - Prime-mover sensor position angle graph

For Figure 4-2 Prime-mover position 1, The angle detected was 77.0547 degree (at 10.7 seconds) and 0 degree (at 14.525 seconds) upon the car pass by the sensor region. Prime-mover position 2, The angle detected was 77.045 degree (at 9.7 seconds) and 0 degree (at 13.525 seconds) upon the car pass by the sensor region. Prime-mover position 3, The angle detected was 77.0503 degree (at 8.675seconds) and 0 degree (at 12.525 seconds) upon the car pass by the sensor region.

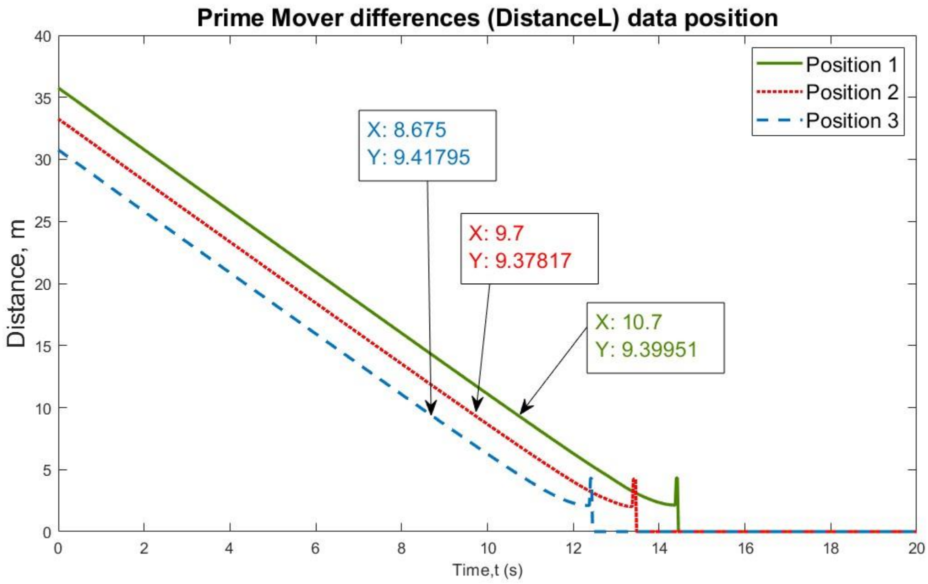


Figure 4-4 - Prime-mover sensor position distance graph

For Prime-mover position 1 figure 4-3, when the car passby the side of the truck, the early warning indicator is displayed on the TruckSim panel within 8.675 seconds until 14.525 seconds within 20 seconds of period. The distance detected position 1 was 9.39951 m (at 10.7 seconds) and 4.3m (at 14.425 seconds) until the car pass through the blind spot region. The distance detected position 2 was 9.37817 m (at 9.7 seconds) and 4.25m (at 13.425 seconds) until the car pass through the blind spot region. The distance detected position 3 was 9.41795 m (at 8.675 seconds) and 4.3m (at 12.425 seconds) until the car pass through the blind spot region.

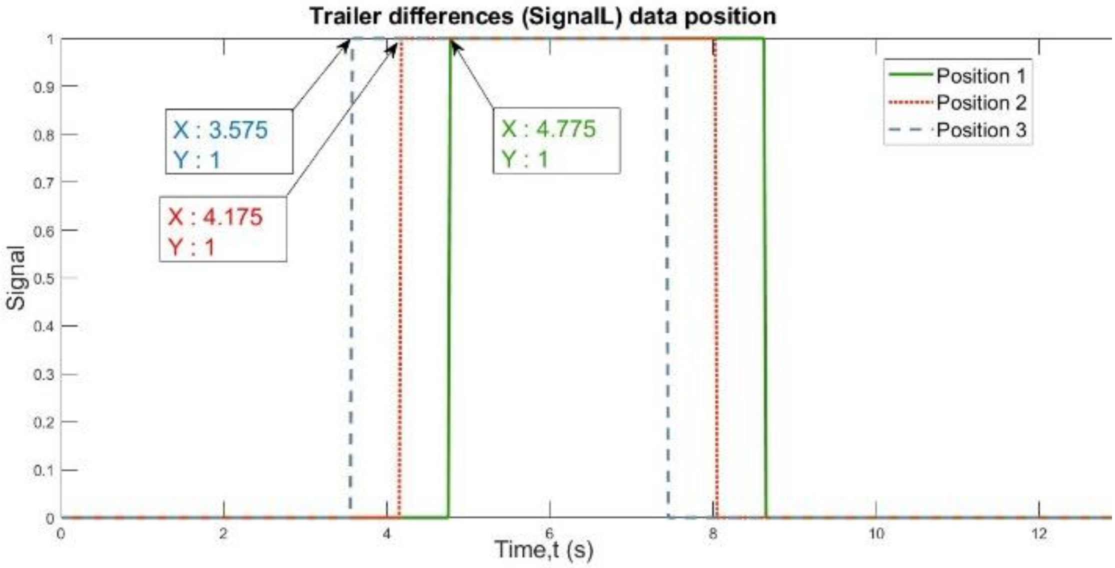


Figure 4-5 - Trailer sensor position signal graph

However figure 4-4 shows for Trailer was also a good position for early time detection because it can detect the vehicle before it happen to pass the truck. For Trailer position 1, when the car passby the side of the truck, the early warning indicator is displayed on the TruckSim panel within 4.775 seconds until 8.625 seconds within 20 seconds of period. A comparison of trailer signal detection between position as shown in Figure 4-4. When the sensor detect upcoming vehicle approach within sensor range in blind spot, the signal will become 1 (ON), signal will turn off after 0 (OFF) when object come out within range. A shown the position 3 trailer setting will be the most optimized due to the early detection.

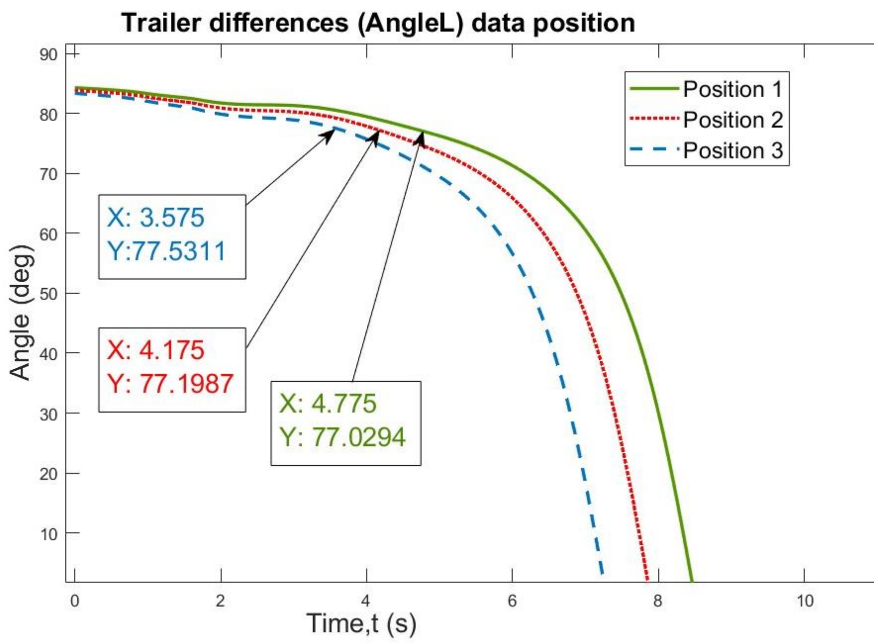


Figure 4-6 - Trailer sensor position angle graph

For Trailer position 1 figure 4-5, The angle detected was 77.0294 degree (at 4.775 seconds) and 0 degree (at 8.625 seconds) upon the car pass by the sensor region. For Trailer position 2, The angle detected was 77.1987 degree (at 4.175 seconds) and 0 degree (at 8.025 seconds) upon the car pass by the sensor region. For Trailer position 3, The angle detected was 77.5311 degree (at 3.575 seconds) and 0 degree (at 7.425 seconds) upon the car pass by the sensor region.

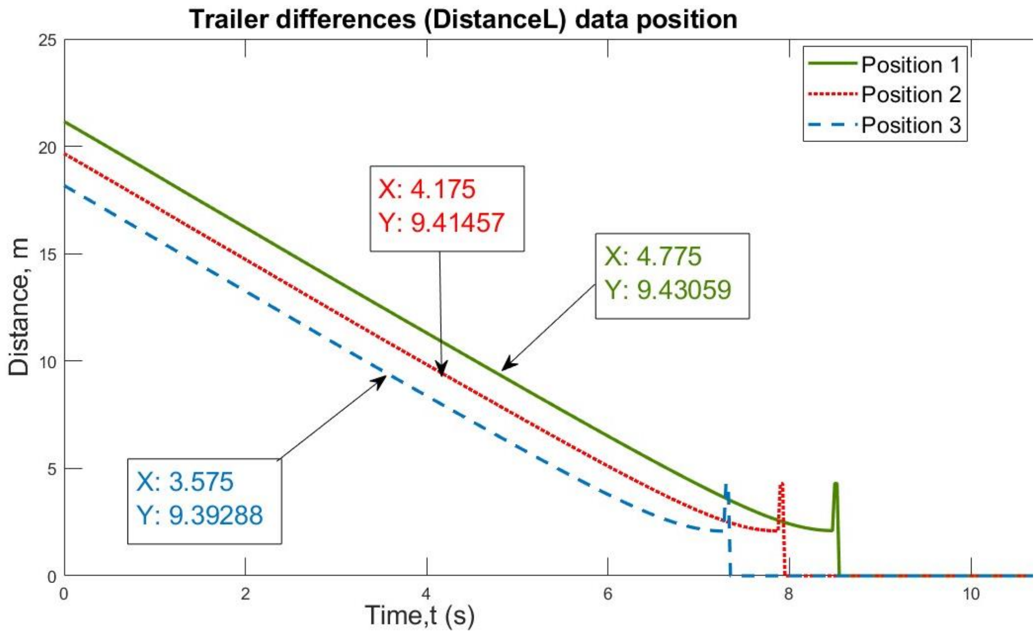


Figure 4-7 - Trailer sensor position distance graph

For Trailer position 1 figure 4-6, The distance detected was 9.43059m (at 4.775 seconds) and 4.3m (at 8.625 seconds) until the car pass through the blind spot region. For Trailer position 2, The distance detected was 9.41457m (at 4.175 seconds) and 4.29m (at 8.025 seconds) until the car pass through the blind spot region. For Trailer position 3, The distance detected was 9.39288m (at 3.575 seconds) and 4.28m (at 7.425 seconds) until the car pass through the blind spot region.

Placement	Position	Initial Detection			Final Detection		
		Time, t (s)	Distance (m)	Angle (deg)	Time, t (s)	Distance (m)	Angle (deg)
Prime	1	10.70	9.40	77.05	14.53	4.33	0.85
	2	9.70	9.38	77.04	13.53	4.25	0.03
	3	8.68	9.42	77.05	12.53	4.30	0.32
Trailer	1	4.78	9.43	77.03	8.63	4.30	0.89
	2	4.18	9.41	77.20	8.03	4.29	0.59
	3	3.58	9.39	77.53	7.43	4.28	0.23

Table 4-1 - Prime and Trailer between 6 different position

The response times for prime and trailer between 6 different position are shown in Table 4-1 sensor detection. As the position sensor position move to the the back the more earlier time detection achieve hence the driver will be alert to the vehicle inside the blindspot. According to Table 4-1 the detection for Prime-mover and Trailer at position 3 has the earliest time detection and the fastest. However we would choose Prime-mover due to the blind spot region reign close beside the truck body rather than behind the trailer. As a result, the most optimum position for sensor positioning for blind spot detection system is at prime mover position 3.

4.3 Summary

Based on the result obtain above, this research concluded that different position result different time detection inside the blind spot zone of sensor detection. For prime-mover the truck detection is generally covering the blind spot zone of the truck which is crucial for placing the sensor at prime-mover rather than the trailer due to limitation of view of the driver since the driver can also see at the side mirror so the trailer position is not sufficent to be choose for an optimum position.

By strategically positioning sensors on both the prime mover and trailer, blind spot detection systems can significantly improve safety by mitigating blind spot-related accidents, providing drivers with crucial information about their surroundings, and enhancing overall awareness while operating heavy vehicles on the road.

In addition to using the Blind Spot Detection Device, drivers can take additional precautions to prevent blind spot accidents. These include having a thorough understanding of the vehicle and its equipment, using vehicles that have ABS, ESP, or equivalent support systems, speaking with loading/terminal staff or the driver who most recently used the vehicle, making sure the load is securely fastened, and planning a route that minimises risks from the weather or the road. A driver's age, health status on a monthly basis, experience operating a truck, and ability to prevent distractions while driving are all important factors to take into account. Use handheld electronics, GPS, and phones only when the car is stationary and the engine is off.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The objective of this project was to determine the optimum sensor position and early warning device for alerting the trucks driver using ultrasonic range finder sensors, an Arduino Due microcontroller and MATLAB Simulink data from the simulation that has been done in the TruckSim as the benchmark. The system employs 1 sensor that is responsible to detect the object within the sensor range of detection based on the blind zone of the heavy vehicle. The range of sensor is concluded to be almost the same at all the different position however the differences is only on the time detection.

The system's response time was found to be within acceptable limits as we scale down to 1:20 size data it was also acceptable and the surface reflectivity of the objects did have a significant effect on the detection rate especially during the final detection after the vehicle pass by the sensor range. In addition, the system was found to be cost-effective and easy to install, making it a suitable alternative to traditional camera or radar-based systems. Furthermore, the system was found to be reliable and the buzzer feature was able to notify the driver if any object were close to 24.7cm diagnolly and 21.5cm parallely.

In summary, the research has successfully shown that it is feasible to use simulation based results to locate items that are within a heavy vehicle's blind spot range and has given important insights into the opportunities and difficulties associated with this kind of technology. The results of this study can serve as a basis for additional investigation and advancement in this field. The technology is simple to install and may be linked into current systems to help increase driver safety while driving.

5.2 Recommendations

For future improvements, the Blind Spot Detection for Heavy Vehicle System Devices accuracy and design estimation results could be enhanced as follows:

i) Combining ultrasonic data with other sensors like radar or cameras for better situational awareness and reduced false alarms

ii) Using higher-frequency (40kHz+) sensors can improve object size and proximity differentiation, especially for motorcycles and bicycles.

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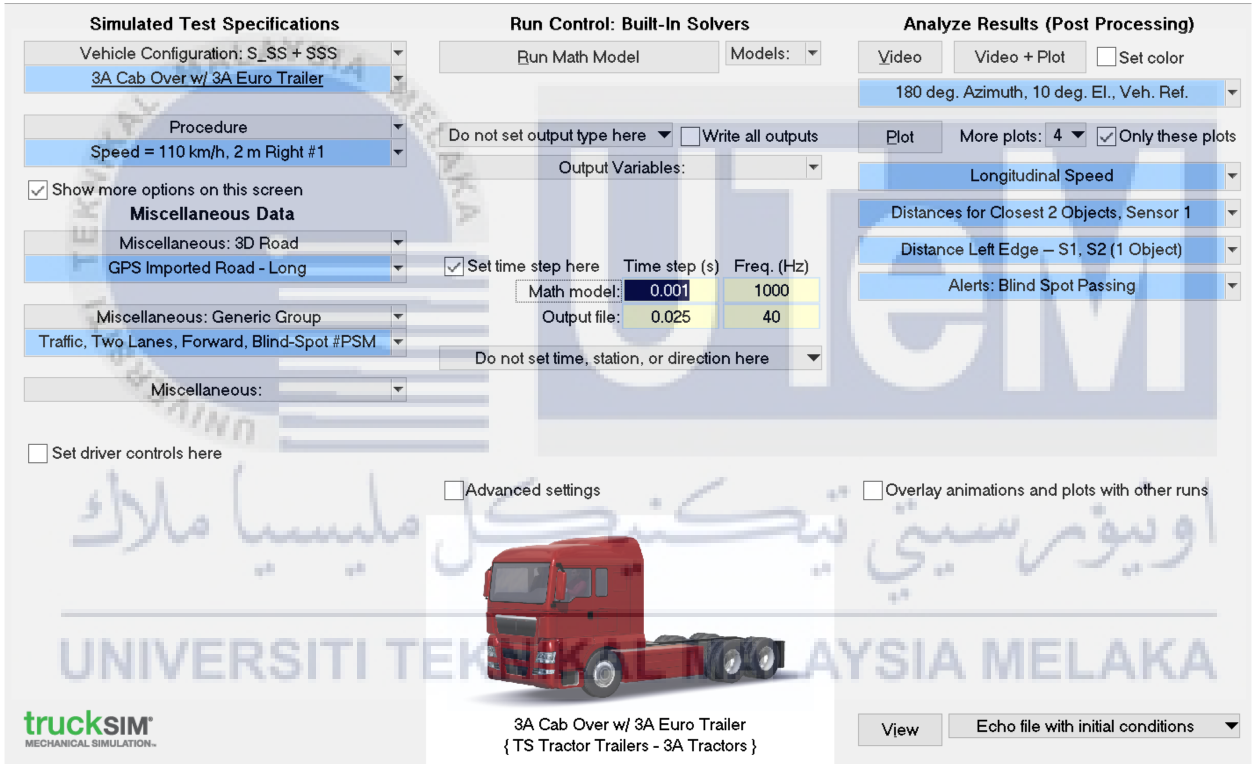
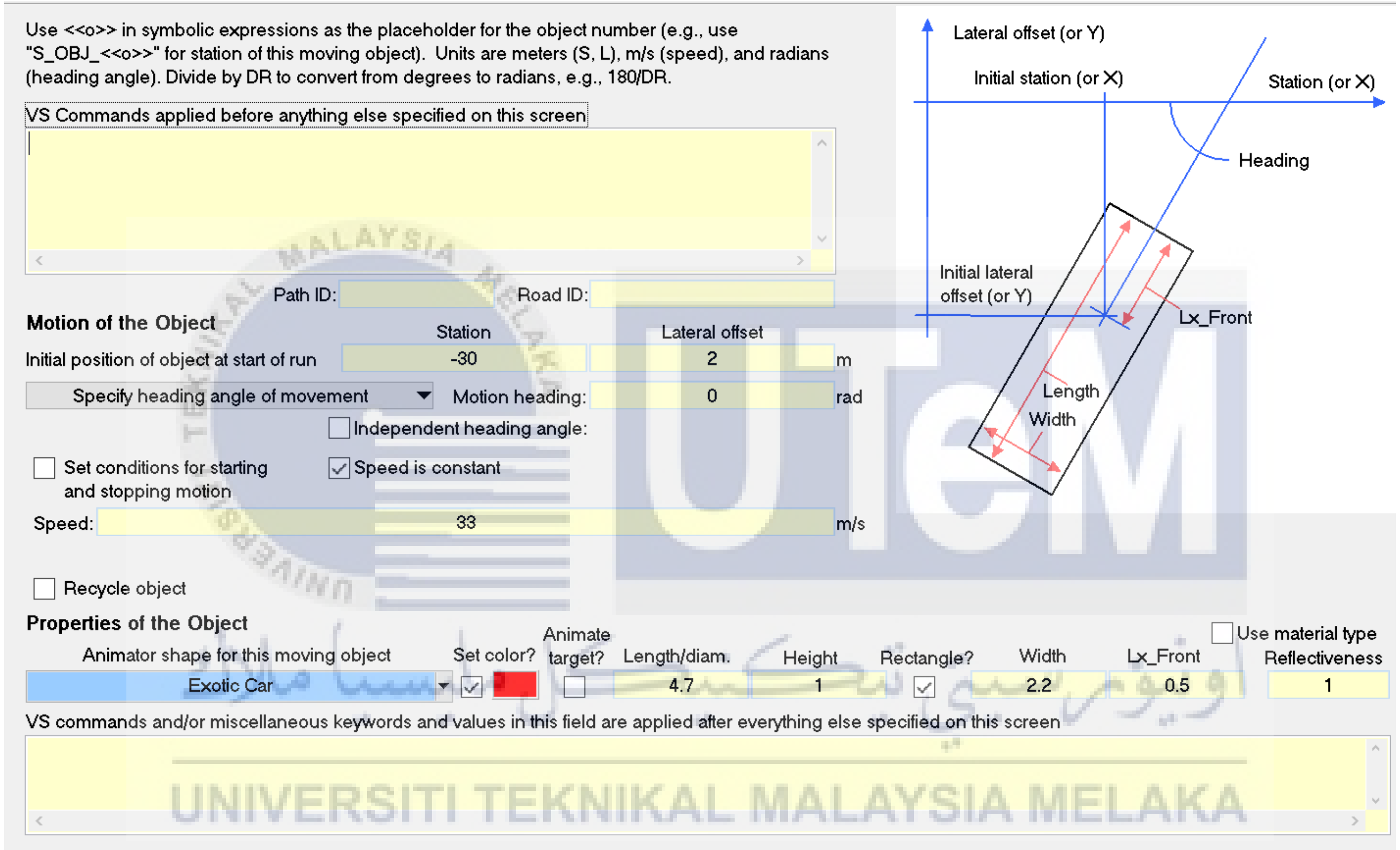
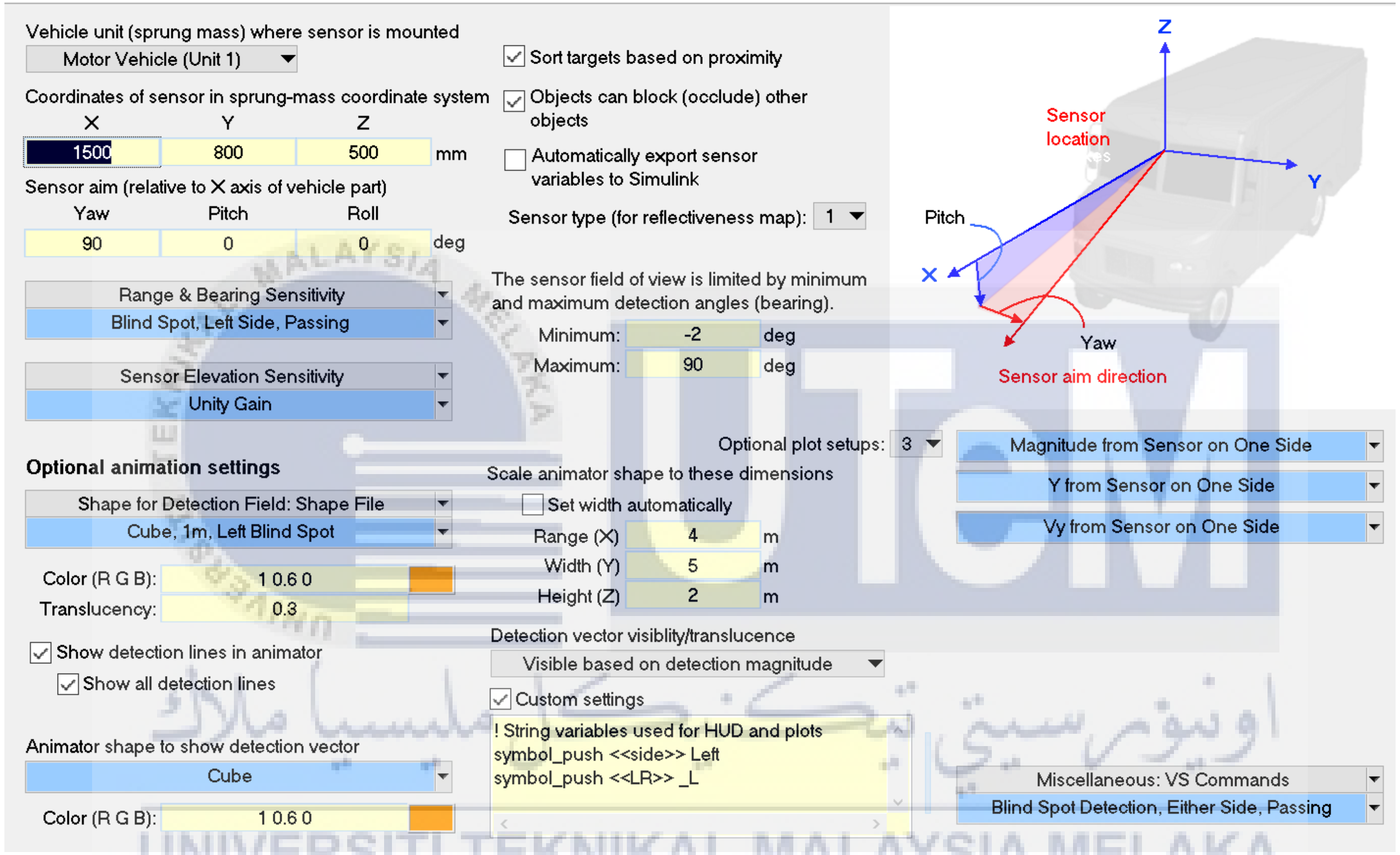
APPENDICES

APPENDIX A TruckSim setup

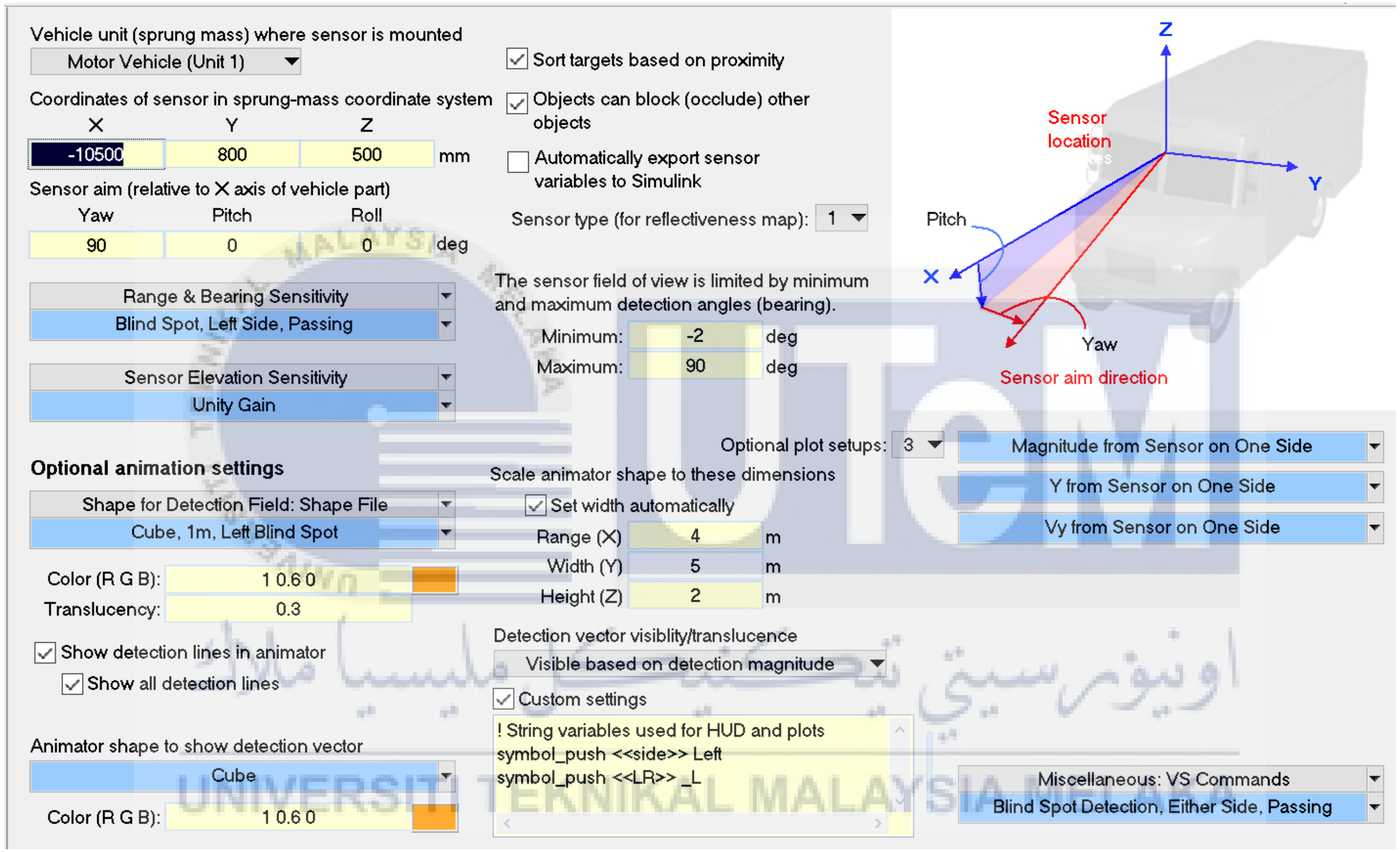



Use <<o>> in symbolic expressions as the placeholder for the object number (e.g., use "S_OBJ_<<o>>" for station of this moving object). Units are meters (S, L), m/s (speed), and radians (heading angle). Divide by DR to convert from degrees to radians, e.g., 180/DR.
VS Commands applied before anything else specified on this screen
Path ID:
Road ID:
Motion of the Object
Station
Lateral offset
Initial position of object at start of run
-30
2
m
Specify heading angle of movement
Motion heading:
0
rad
Independent heading angle:
Set conditions for starting and stopping motion
Speed is constant
Speed:
33
m/s
Recycle object
Properties of the Object
Animator shape for this moving object
Exotic Car
Set color?
Animate target?
Length/diam.
4.7
Height
1
Rectangle?
Width
2.2
Lx_Front
0.5
Use material type
Reflectiveness
1
VS commands and/or miscellaneous keywords and values in this field are applied after everything else specified on this screen
Lateral offset (or Y)
Initial station (or X)
Station (or X)
Heading
Initial lateral offset (or Y)
Lx_Front
Length
Width

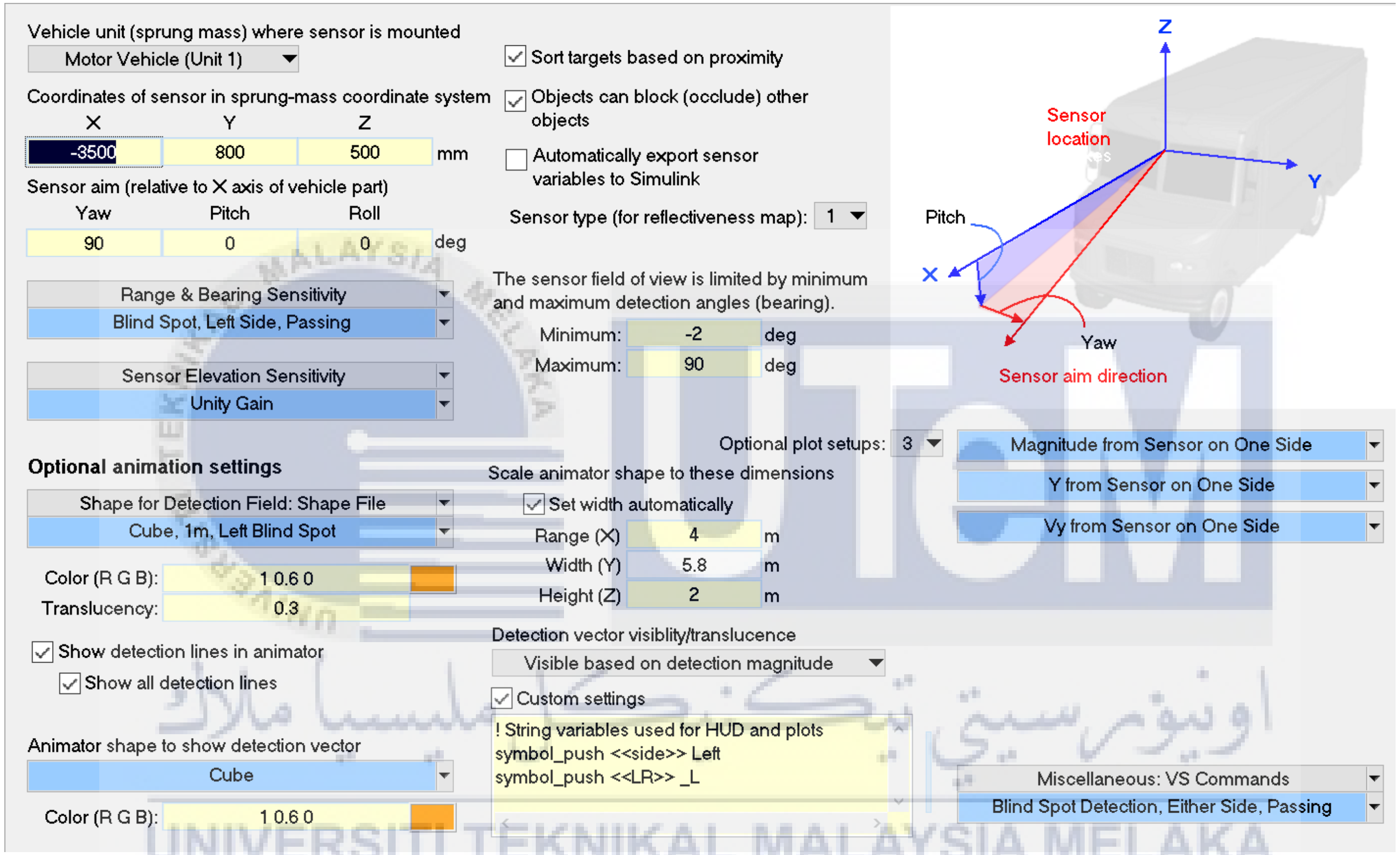
Passby Car



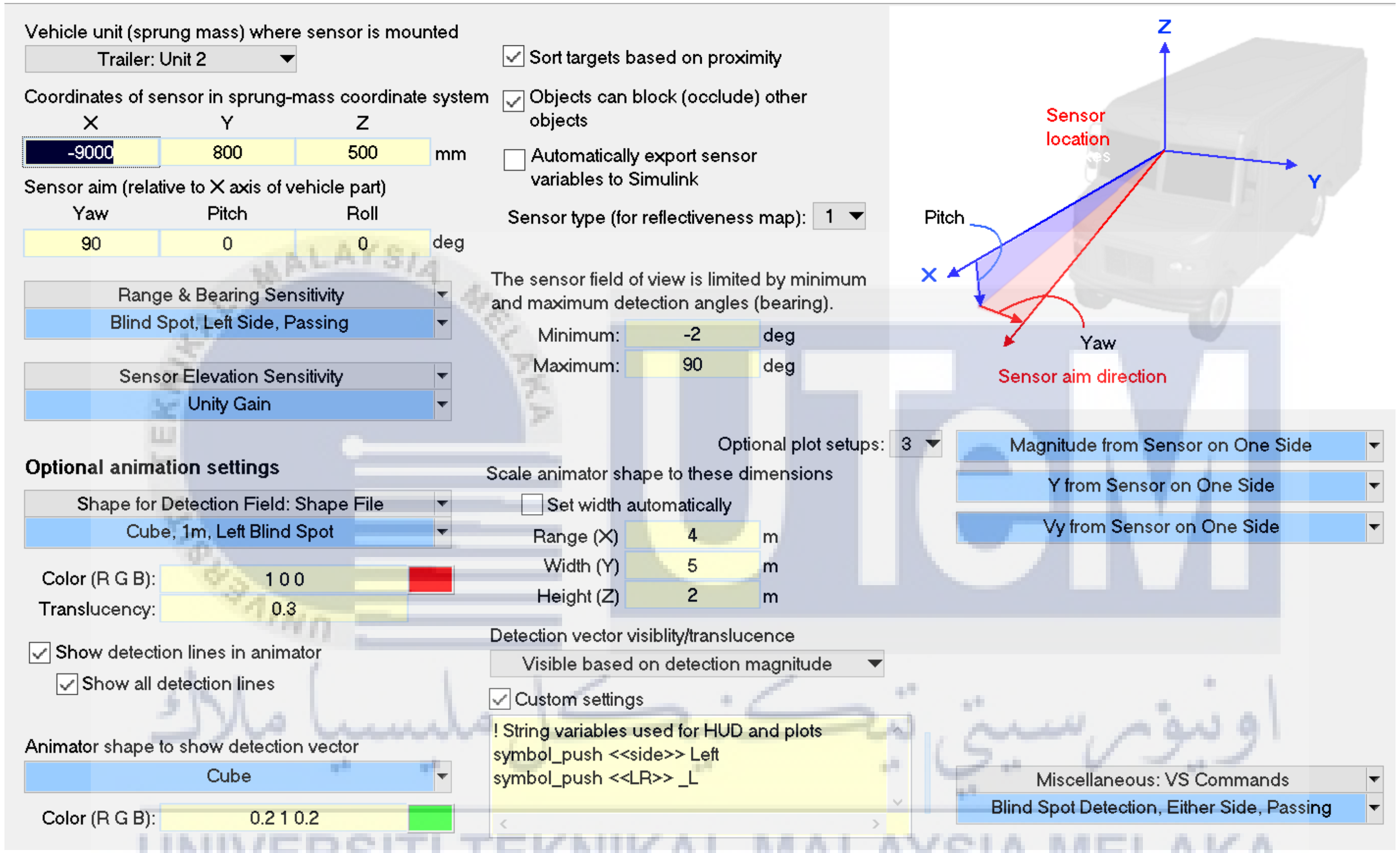
Prime-Mover position 1



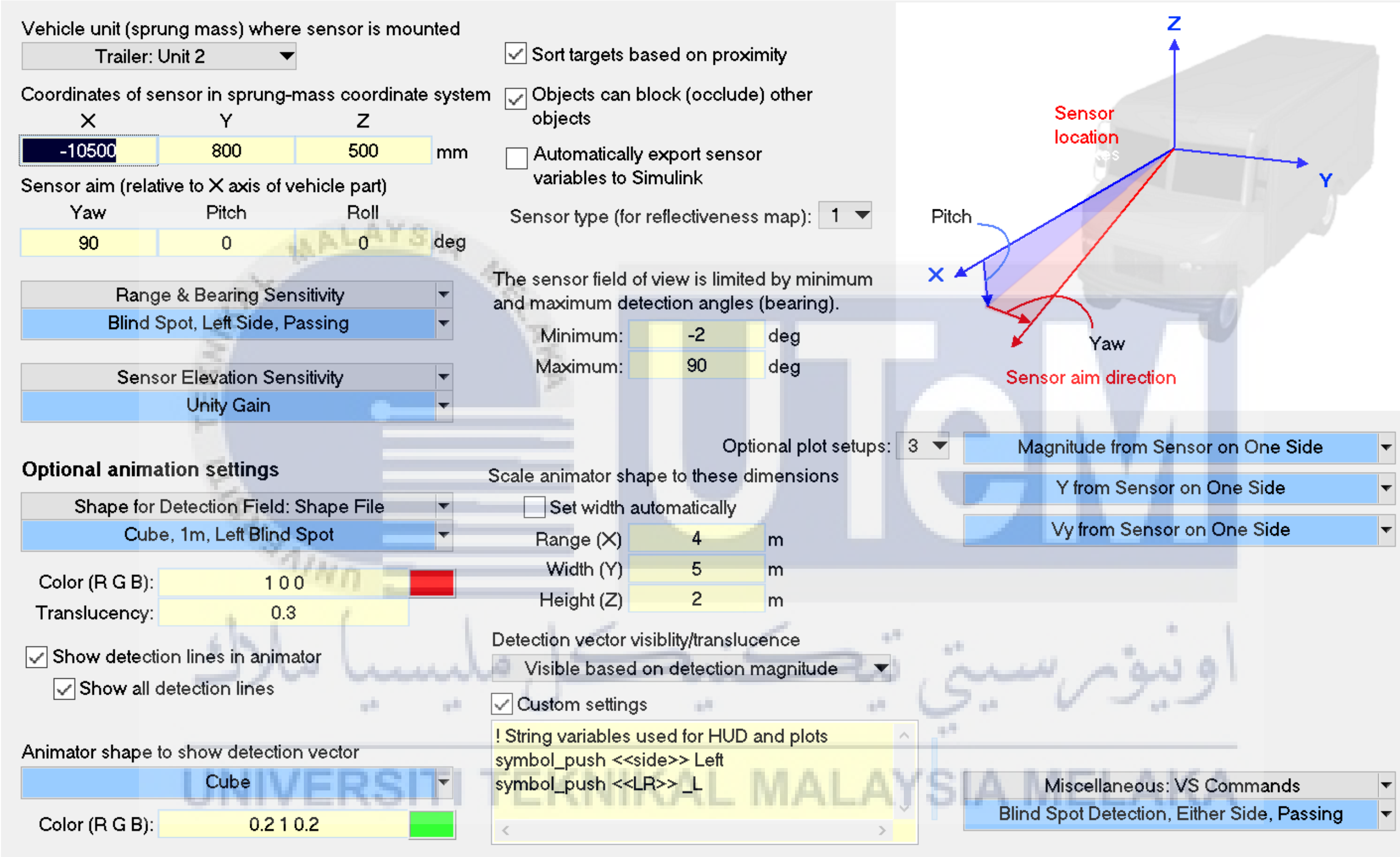
Prime-Mover position 2



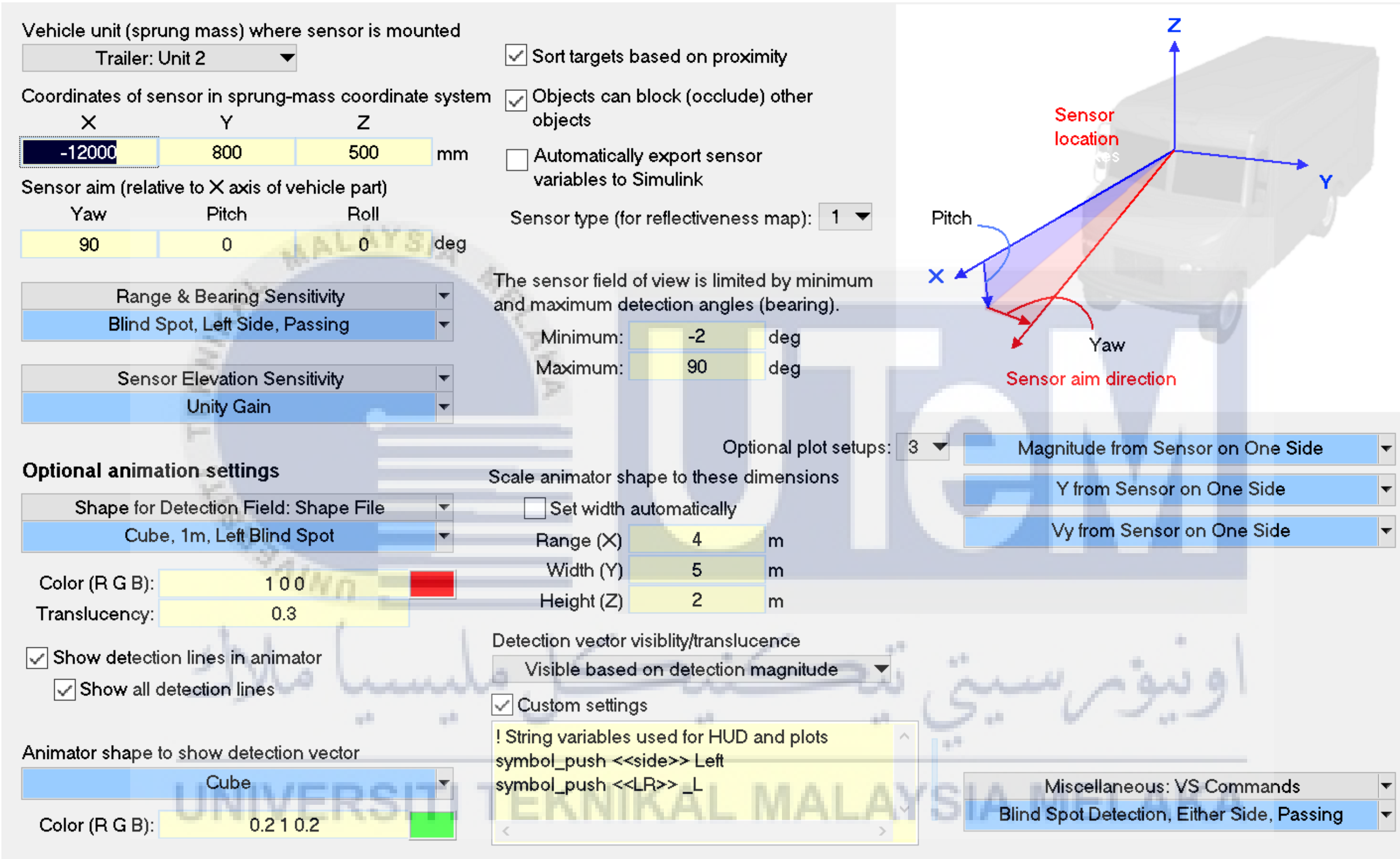
Prime-Mover position 3



Trailer position 1



Trailer position 2



Trailer position 3

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Tuan

PENGKELASAN TESIS SEBAGAI TERHAD BAGI TESIS PROJEK SARJANA MUDA

Dengan segala hormatnya merujuk kepada perkara di atas.

2. Dengan ini, dimaklumkan permohonan pengkelasan tesis yang dilampirkan sebagai TERHAD untuk tempoh **LIMA** tahun dari tarikh surat ini. Butiran lanjut laporan PSM tersebut adalah seperti berikut:

Nama pelajar: MUHAMMAD ARIF LUKMAN BIN MUHAMMAD SABRI (B092010078)
Tajuk Tesis: DEVELOPMENT OF BLIND SPOT DETECTION SYSTEM FOR HEAVY VEHICLE

3. Hal ini adalah kerana IANYA MERUPAKAN PROJEK YANG DITAJA OLEH SYARIKAT LUAR DAN HASIL KAJIANNYA ADALAH SULIT.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"
"KOMPETENSI TERAS KEGEMILANGAN"

Saya yang menjalankan amanah,

IR. TS. DR. MOHAMAD HAFIZ BIN HARUN
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