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DEVELOPMENT OF BLIND SPOT DETECTION SYSTEM FOR COMMERCIAL VEHICLE

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DEDICATION

I dedicate this thesis to the cherished individuals whose unwavering support and encouragement have been instrumental in this journey. Their love, guidance, and inspiration have shaped my academic pursuit, and for that, I am profoundly grateful.

To my parents, Bedu Arifin Bin Kadir and Masni Binti Samsuddin. Your boundless love, sacrifices, and enduring belief in my abilities have been my greatest motivation. This achievement is as much yours as it is mine. Thank you for being the pillars of strength in my life.

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ABSTRACT

Accidents involving commercial vehicles have increased recently. These accidents are frequently followed by severe injuries or even fatalities and can be exceedingly dangerous. This report's objective is to assess how well commercial vehicle blind spot detection systems utilize ultrasonic sensors. The study used the simulation from TruckSim software and MATLAB Simulink. Ultrasonic sensors with an Arduino Due are used to detect objects in a commercial vehicle's blind area based on time response and optimum position sensor. The findings demonstrated that the system had a high detection rate and a quick response time for finding items in a commercial vehicle's blind zone to give early warning to the driver.

ABSTRAK

Kemalangan yang melibatkan kenderaan komersial semakin meningkat sejak kebelakangan ini. Kemalangan ini sering diikuti oleh kecederaan parah atau bahkan kematian dan boleh menjadi sangat berbahaya. Objektif laporan ini adalah untuk menilai sejauh mana sistem pengesan titik buta kenderaan komersial menggunakan penderia ultrasonik. Kajian ini menggunakan simulasi daripada perisian TruckSim dan MATLAB Simulink. Penderia ultrasonik dengan Arduino Due digunakan untuk mengesan objek dalam kawasan buta kenderaan komersial berdasarkan tindak balas masa dan kedudukan optimum bagi penderia. Penemuan menunjukkan bahawa sistem itu mempunyai kadar pengesanan yang tinggi dan masa tindak balas yang cepat untuk mencari item dalam zon buta kenderaan komersial bagi memberi amaran awal kepada pemandu.

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CHAPTER 1

INTRODUCTION

1.1 Background

Commercial vehicles have significantly improved people's lives during the past few decades. Vehicles are become a necessary component of daily life. Users may now go much further and faster because of their efforts.

Apart from the beneficial impacts transportation brings to society, it also gives rise to adverse effects, notably fatal accidents. Injuries resulting from road accidents stand as a prominent global cause of mortality, ranking second only to conditions like chronic obstructive pulmonary disease, stroke, lower respiratory infections, trachea, bronchus, lung cancers, and diabetes. This issue particularly affects children and young adults aged 5–29, emerging as the leading cause of death within this demographic. The World Health Organization (WHO) highlights in its report that road accidents account for a staggering 1.35 million deaths annually, equivalent to the combined impact of various other contributing factors. The incidence of road-related fatalities has shown an upward trend, peaking at 1.35 million in 2016 (*GLOBAL STATUS REPORT ON ROAD SAFETY 2018*, n.d.)

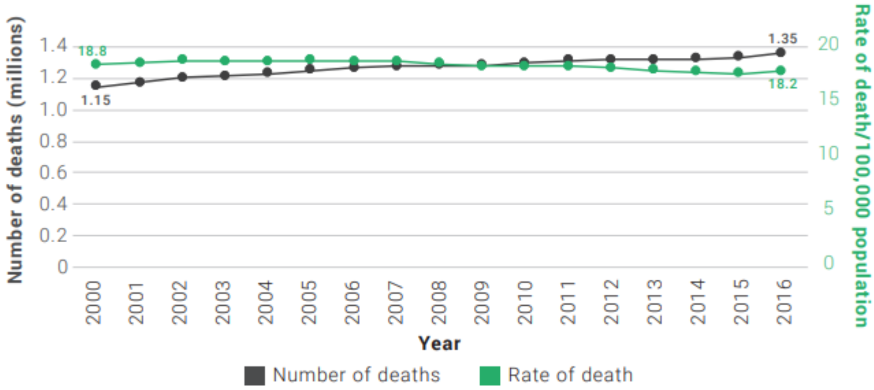


Figure 1.1 Number and rate of road traffic death per 100,000 population : 2000-2016**(*GLOBAL STATUS REPORT ON ROAD SAFETY 2018*, n.d.)**

In Malaysia, the annual number of fatalities resulting from road accidents saw a consistent rise between 2014 and 2016, accompanied by an 8.37% increase in the involvement of vehicles throughout this period. This surge in road accidents, when viewed in the context of Malaysia's population of 28 million, reflects a notably high rate. The frequency of traffic accidents in the country has demonstrated sporadic escalation, as evidenced by the Ministry of Transport Malaysia's recording of 567,000 road accidents in 2019, marking an increase from the 548,598 cases documented in 2018. Fatal accidents, numbering 6,167 cases in 2019, were also a concerning aspect. Malaysia, statistically, stands out among ASEAN nations for having one of the highest rates of road fatalities relative to its overall population (Fallis, 20155). According to national statistics from the Royal Malaysian Police, motorcycle riders are identified as significant contributors to a considerable portion of fatal accidents. (Khairul Amri Kamarudin et al., 2018)

According to National Highway Traffic Safety Administration (NHTSA), people killed in traffic crashes in 2021 is increased 10% which is from 39007 in 2020 to 42939 in 2021 this includes passenger vehicles, passenger cars, light trucks, SUVs, pickups, vans, large trucks, motorcyclists, pedestrians and pedal cyclists (Hs, 2023). Road accidents are frequently described as unfavourable incidents that happen when a driver lost control of their vehicle and collides with an object, or when a vehicle crashes, resulting in either property loss, fatalities to the driver, passengers, and other drivers (Nations & Committee, 2013). According to the Malaysia Road Accident Statistics Report 2012, a road accident in Malaysia is defined as an incident that occurs on a private or public road and occurs by human error, environment, or any collision involving at least one moving vehicles, where is damage or injury including death that faced by anybody, property, vehicle, structure or animal that involve the incident (Sarani et al., 2012). The road accident usually caused by combination of factors which is behaviour of driver, infrastructure of road quality, traffic volume and the environment (Jaafar et al., 2003). Among all of these factors, one that contributes to road accidents is blind spot.

The National Highway Traffic Safety Administration (NHTSA) suggests that over 800,000 collisions in blind spots happen each year, resulting in 300 fatalities. Addressing and resolving the blind spot issue has the potential to significantly decrease the percentage of accidents.

1.2 Problem Statement

According to statistics, visual issues such nighttime light brightness and glare, blind spot areas and driver eyesight were to blame for the majority of traffic incidents. The area directly in front of the car that the driver cannot see while driving is known as the blind spot. Commercial vehicle operators face challenges in observing specific areas along the road, both in front of, behind, and on either side of their vehicles. Various elements, such as the design of the driver's seat, road layout, and the vehicle's body structure, contribute to obstructing a driver's forward view or creating blind spots. These blind spots in the rear or sides of commercial vehicles can completely conceal pedestrians, small motorcycles, or even entire vehicles. Due to these blind spots, it becomes crucial for drivers to thoroughly check the road before undertaking maneuvers like changing lanes, turning, overtaking, or reversing to ensure the safety of all road users. This causes the driver in a dangerous scenario that occasionally leads to accidents and unfortunate situations.

Figure 1.2 illustrates an accident that occurred because of the blind spot area. When the interior rear view mirror, and sideview mirror obstruct the driver's view of the road, a blind spot may develop in front of the driver. The existence of headrests, additional containers and passengers behind the driver could limit the view. Vehicle speed has an impact on blind spots since they enlarge significantly as speed increases. Additionally, the size of the vehicle affects the blind spot. As a result, it increases the potential that these vehicles would have larger blind areas (Kedarkar et al., 2008).

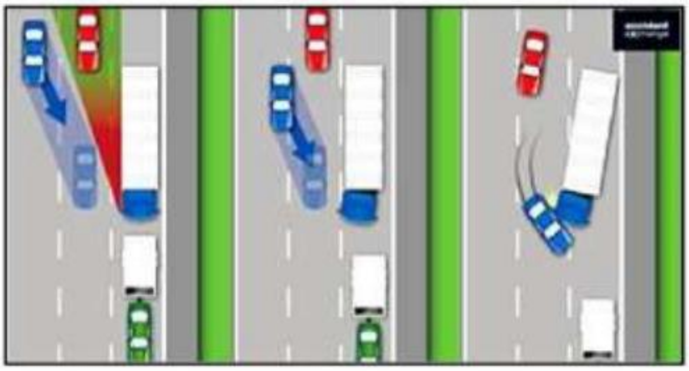


Figure 1.2 Accident Caused by Blind Spot (Kedarkar et al., 2008)

According to Malaysia Institute of Road Safety Research (MIROS), the distribution of accident cases by type of collision for commercial vehicle in both year 2013 and 2014 was reported. The run-off cases had the highest scores out of all crashes and represented almost half of all accidents (52.7% for 2013 and 51.3% for 2014). The second highest type of accident was rear-ended collision which reported about 28.8% to nearly 30% of the total collisions. Side swipe accident recorded about 2.9% only, although its like small amount, it still can cause an accident to occur or more serious death case risk (Sim et al., 2020).

According by Malaysian Institute of Road Safety Research (MIROS) to Malaysia road accident factors in 2011 as shown in Figure human error dominates 80.6% of the major factors in road accidents, followed by road infrastructure and environment (13.2%), and vehicle condition (6.2%) (Idris et al., 2019).

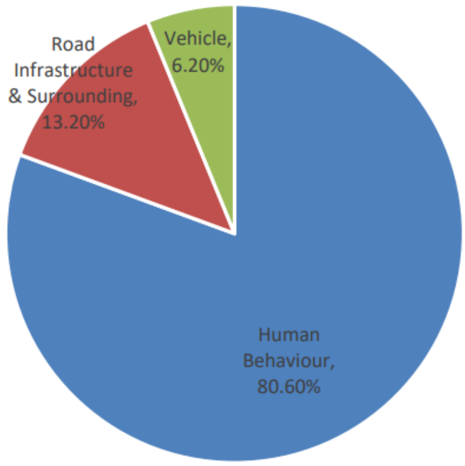


Figure 1.3 Cause of Accident Source: Malaysia Institute of Road Safety Research (MIROS) **(Idris et al., 2019)**

As a result, side swipe occurs because the driver usually cannot see the side of the vehicle in the blind spot area. Unconsciously, there is no application to detect blind spots in most commercial vehicles due to human error, even though the existing ones on trucks are not able to provide accurate data to the driver and accidents still occur. In this study, the driver's vision to the vehicle blind spot is improved by determining the optimal position and time response with the vehicles before the collision, because of that the point for the blind spot needs to be studied. Taking the initiative to reduce human error while helping to reduce the risk of accidents by warning the driver to be alert.

1.3 Research Objective

The aim of the research is to create a blind spot detection system for commercial vehicle which could minimize the risk of truck being on an accident. The objectives are as follows:

a) To identify the optimum sensor position for blind spot detection system for commercial vehicle.

b) To identify the configuration of blind spot detection system for commercial vehicle.

1.4 Scope of Research

The following are the scope of the research:

- A microcontroller is applied to construct and develop commercial vehicle blind spot detection system device.
- The best position for sensor placement is obtained based on coverage area of commercial vehicle on different location.
- The tests are performed in this study based on time response to identify the sensor configuration.
- The experiment is evaluated to improve the commercial vehicle blind spot detection system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The focus of this literature review is to study and assess the body research already in existence and recent developments in the area of commercial vehicle blind spot detection systems. This review aims to provide a thorough overview of the current state of the field, highlight the main challenges and difficulties, and propose potential avenues for future research and development.

2.2 Blind Spot

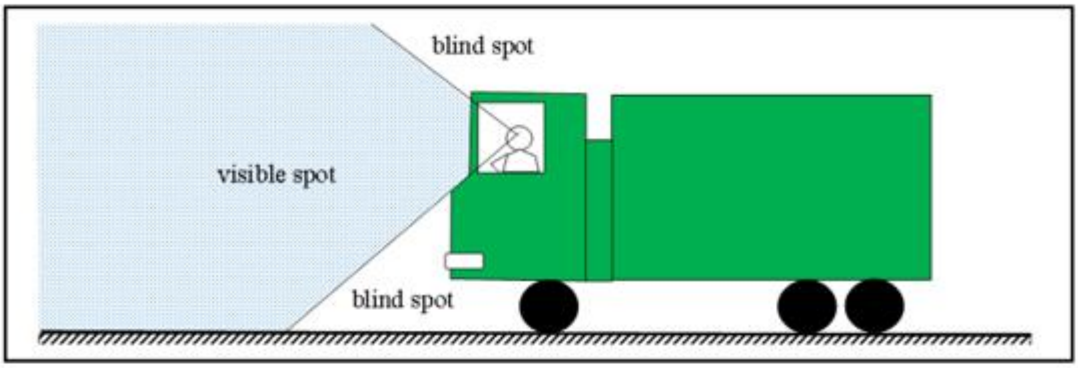
The parts of the road known as blind spots are those that cannot be noticed when looking forward or through the mirrors. Blind spots that tend to occur most frequently are those that are present on both sides of the commercial vehicle's rear. Other locations that are commonly referred to as blind spots include areas that are way too low to see behind to the sides of a car or in front of, particularly those with a high seating position, such vans and trucks.

2.2.1 Blind Spot Region

Usually, the sides of the truck, particularly the right side, from the side mirrors to the back of the cab, are considered as a blind spot. Trucks also have blind spots during turns due to off tracking, in which the rear wheels take a narrower route than the front wheels.

Figure 2.1 Trucks (Volvo Trucks)

The front window, together with the left and right windows, are all directly visible to the driver. The A pillars and mirrors cover the front corners on the left and right. Due to the driver's high position over the road, the area around the cab is obscured (Mazankova, 2015).



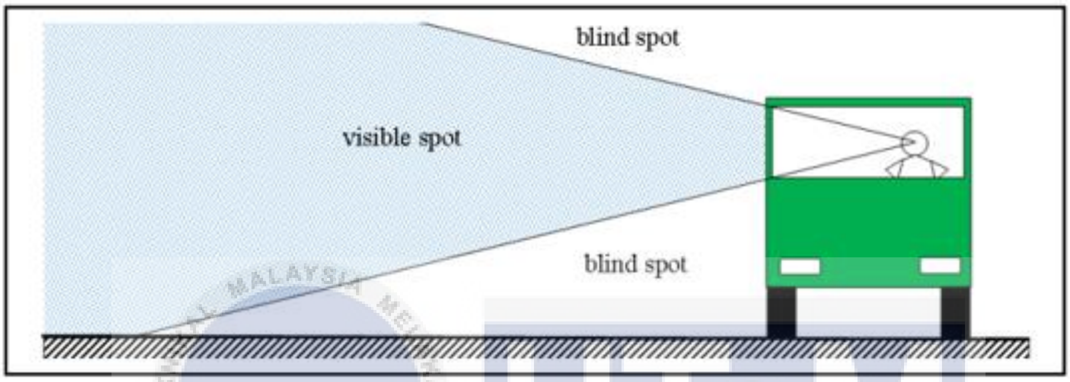


Figure 2.2 View by front window and side window **(Mazankova, 2015)**

2.2.2 Type of Blind Spot Accident

When changing lanes, numerous traffic accidents often occur due to negligent driving and insufficient awareness of blind spots. In situations where a driver fails to check the side mirror, resulting in an inability to observe the rear-side blind spot, or attempts to change lanes without proper visibility, the potential for collisions with approaching vehicles from the rear is ever-present. To mitigate accidents stemming from the side or rear of the host vehicle during lane changes, the implementation of a vehicle detection system, such as the Blind Spot Detection System, proves crucial. These systems enhance the driver's visibility and provide timely notifications regarding the approaching speed of vehicles in the rear-side vicinity. (Prentkovskis et al., 2010).

2.3 Vehicle

Heavy-duty vehicles are made in a variety of sizes depending on their weight, length, and axle count. This aspect makes it challenging to categorise a single decent vehicle because different countries may have different classification systems. The vehicle classes in Malaysia are clearly defined in the appropriate rules, however none of these are reduced into a graphical format that is simple to comprehend. As indicated in figure 2.7, a graphic form created by PLUS Malaysia Berhad is accessible on their website.

Class	Icon	Description
Class 1		Vehicles with 2 axles and 3 or 4 wheels excluding taxis
Class 2		Vehicles with 2 axles and 5 or 6 wheels excluding buses
Class 3		Vehicles with 3 or more axles
Class 4		Taxis
Class 5		Buses

Figure 2.3 Vehicle classes (Source: PLUS Malaysia Berhad)

Figure 2.8 illustrates number common types of trucks. Rather of showing several body types, the pictures presented in figure 2.8 are intended to show how an axle and hitch are configured. Vans are the only body types shown, however other body types, such as flat-bed or platform, tanker, dump, and others, might potentially be used in the truck combinations. The tractor-trailer combination consists of a single semitrailer being pulled by the truck.

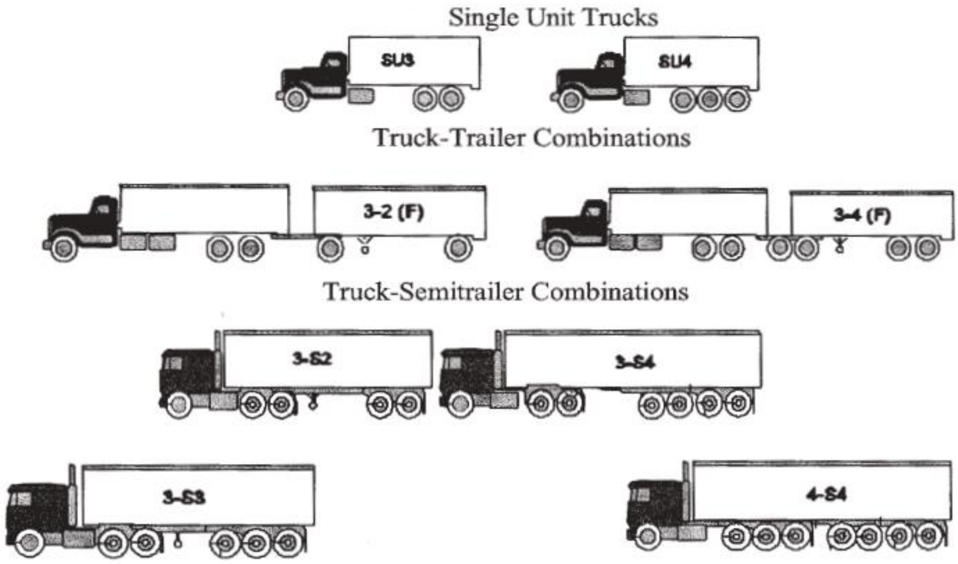


Figure 2.4 Illustrative truck configurations (“Rev. Truck Charact. as Factors Roadw. Des.,” 2003)

2.3.1 Type of Commercial Vehicle

A commercial vehicle is employed for business or commercial activities. When a vehicle is titled or registered under a corporation, it is commonly known as "commercial." This classification extends to fleet vehicles, corporate cars, or any other vehicles utilized for business purposes. The Federal Motor Carrier Safety Administration (FMCSA), responsible for regulating commercial vehicles, offers a more specific definition, indicating that a commercial vehicle possesses a gross combined weight rating of 4,537 kg (10,001 lb) or more.

(Yang et al., 2016) study looked into the truck acceleration performance at metered on-ramps using the Federal Highway Administration's (FHWA) vehicle classification standard. Light trucks, medium trucks, and heavy trucks are the three classifications for trucks. The detail of each truck category is shown in figure. The Gross Vehicle Weight

(GVW) of light trucks can reach 11000lb (5000kg). In urban and suburban locations, they are frequently employed for small-scale deliveries. While medium trucks is between 11000lb and 33000lb (5,001kg to 15,000 kg). For medium-scale transportation operations nationwide freight shipping, involving the regional distribution of resources, they are more potent and appropriate. Generally, the Gross Vehicle Weight (GVW) of heavy trucks is more than 33000lb (15000kg), made for long-distance.

Truck type defined in this study	FHWA vehicle classification	Vehicle description	Typical model
Light truck	Class 5	Single unit 2-axle trucks	
Medium truck	Class 6 & 7	Single unit, 3 or more axles trucks	
Heavy truck	Class 8 & 9	Single trailer, 3, 4, 5 axles trucks	

Figure 2.5 Truck type defined in the study **(Yang et al., 2016)**

Figure 2.6 2-axle straight trucks (Isuzu Malaysia)

2.4 Warning Device

The primary algorithm of ADAS-systems when a vehicle is in motion involves obtaining data from sensors all around it, identifying potentially dangerous situations on the road, and taking action to prevent or lessen the effects and further analysis. The vehicle is installed with warnings (audio and visual), various types of sensors and information output devices (displays) to carry out these actions.

2.4.1 Sensor in Blind Spot Detection System

The vehicle detection system incorporates an IR (Infrared) sensor, ultrasonic sensor, radar sensor, and a vision sensor. The vision sensor, employed in both the vehicle detection system and Lane Change Assistance (LCA) system for lane detection, stands out. Numerous studies have utilized cameras for object detection through a vision sensor. The identification of objects using a vision sensor relies on image data, and certain algorithmic features applicable to vehicle detection can also be employed in this context.

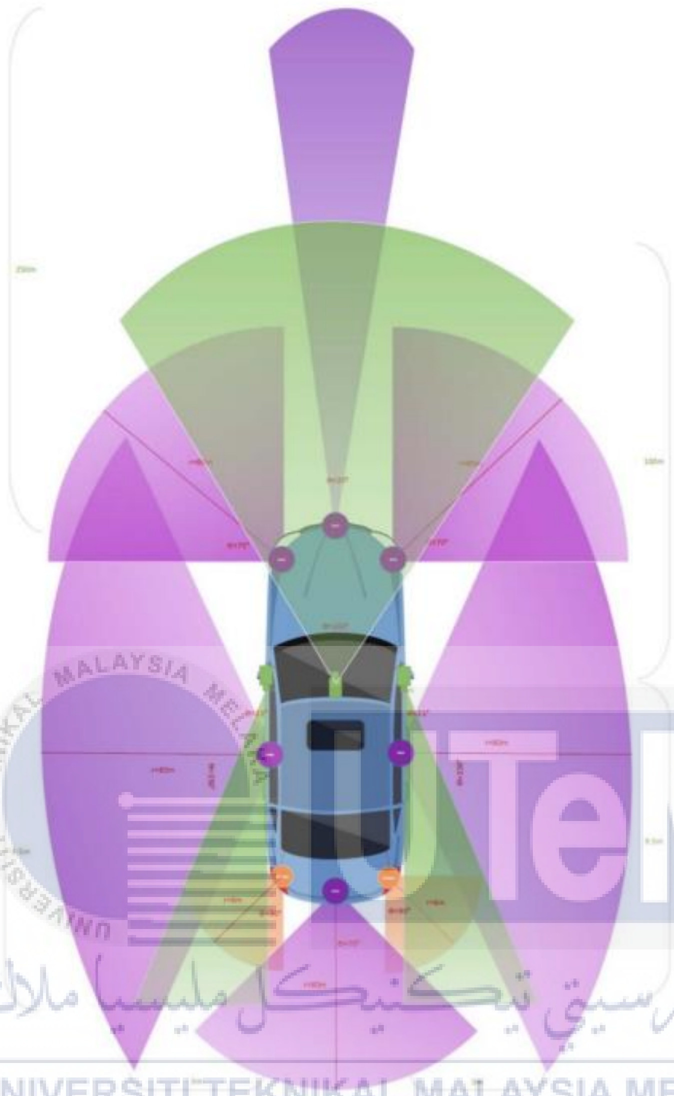


Figure 2.7 Proposed sensing structure. Radar sensors, cameras and ultrasonic sensors are shown in purple, green, and orange colors respectively **(Bagi et al., 2019)**

Radars with short and long ranges can measure an object's velocity and distance with great resolution. Due to the great resolution of radar sensors, clustering is a crucial stage in radar detections (Schubert et al., 2015). In any type of weather, ultrasonic sensors can detect incoming vehicles at low speed. (Jo & Jung, 2014) provides a description of the vehicle detection method using ultrasonic sensor distance data. Hierarchical clustering and K-means are two algorithms that are sensitive to noise and outliers. (Jin et al., 2017) describes a clustering approach for radar detections called density-based spatial clustering of applications with noise (DBSCAN). To identify the observed objects and improve the detection accuracy, cameras can extract the object's attributes and integrate it with the data from ultrasonic and radar sensors. For vehicle identification with cameras, a combination of depth wise separable convolution, squeeze-and-excitation and residual learning might be utilised because processing time is one of the key aspects in Blind Spot Detection system. (Zhao et al., 2019).

2.4.2 Sensor Positioning

Publications based on heavy goods vehicle accident reconstruction studies state that almost all of the vulnerable road users were on the right side of the truck when the accident occurred (Ceunynck et al., 2018). Figure 2.12 illustrates different zones around the truck. The double blue line regions are clearly visible from the truck's driver seat through the windows. The sections with orange dashed lines and solid are visible through the vehicle's mirrors. Through the windows and mirrors, the sections with the red squares are not visible from the cabin. These areas are referred as "blind spots". Important to highlight that all regions were created using the truck's position in Figure 2.12 as the reference. The blind spot region is increase while the area visible through the mirror is decrease when the truck moves to the right (De Raeve et al., 2020)

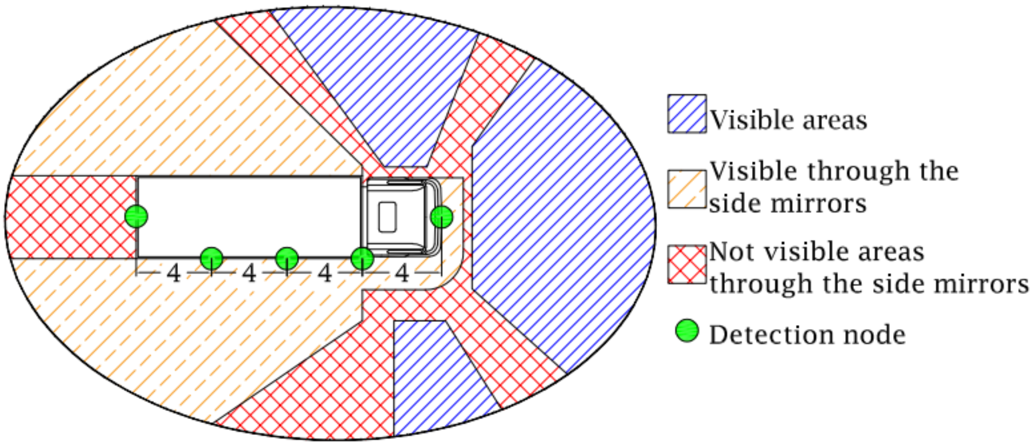


Figure 2.8 Red crossing lines indicate areas that cannot be seen through the side mirrors, or the blind spot area. The green dots are truck with all mounted detecting nodes and all surrounding blind areas, dashed and solid orange lines indicate areas that can be seen through the side mirrors, double blue lines indicate regions that can be seen through the windscreen (De Raeve et al., 2020)

(Hartstern et al., 2020) An overview of factors related to various sensor placements is shown in figure 2.13. The statement "the higher, the better" is present on (a), as high-placed sensors have a better view of the scene and able to see beyond obstructions. On (b), there are scenarios in which even high-placed sensors' field of vision is constrained, making it more beneficial to 'see around the corner' with a sensor located on an exterior component of the vehicle. Scenario (c) is an exception since higher sensors can see around the obstruction earlier. In order to avoid missing any objects that are extremely near to the vehicle, it is also crucial to examine the position-dependent blind spot region (d).

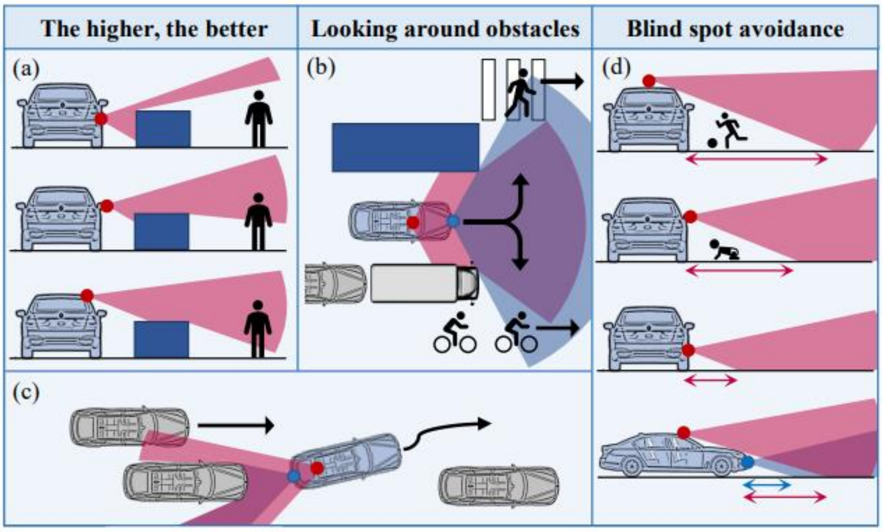


Figure 2.9 Advantages and disadvantages of different sensor mounting positions **(Hartstern et al., 2020)**

2.5 Implementation and Testing

Software in the Loop (SIL) simulation was used for testing and implementation. The use of Software In the Loop (SIL) solutions allows for the testing of generated solutions using simulations of real-world circumstances. Their use reduces the requirement for physical prototypes and testing while improving development and quality control.

2.5.1 Software In the Loop (SIL)

In other words, the use of this Software-in-the-loop (SIL) approach verifies existing software without the requirement for framework-specific implementations. Additionally, real embedded software testing rather than system-level or conventional network simulations enables quicker and more effective debugging (Alonso-Eugenio et al., 2020). Testing of pre-production design is another benefit of using Software-in-the-Loop (SIL) models. The general behaviours and characteristics of a design may be determined using this method, which is incredibly efficient and effective.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This part will discuss about the methodology used in conducting this project. This chapter also contains test in progress and information gathered. Blind spot detection system is developed to overcome this commercial vehicle accident concern. Its purpose is to provide the driver with and early warning before the collision based on the best position sensor and time response. The microcontroller Arduino Due with other equipment are used through the TruckSim Software and MATLAB Simulink to perform this project.

3.2 Flowchart Process

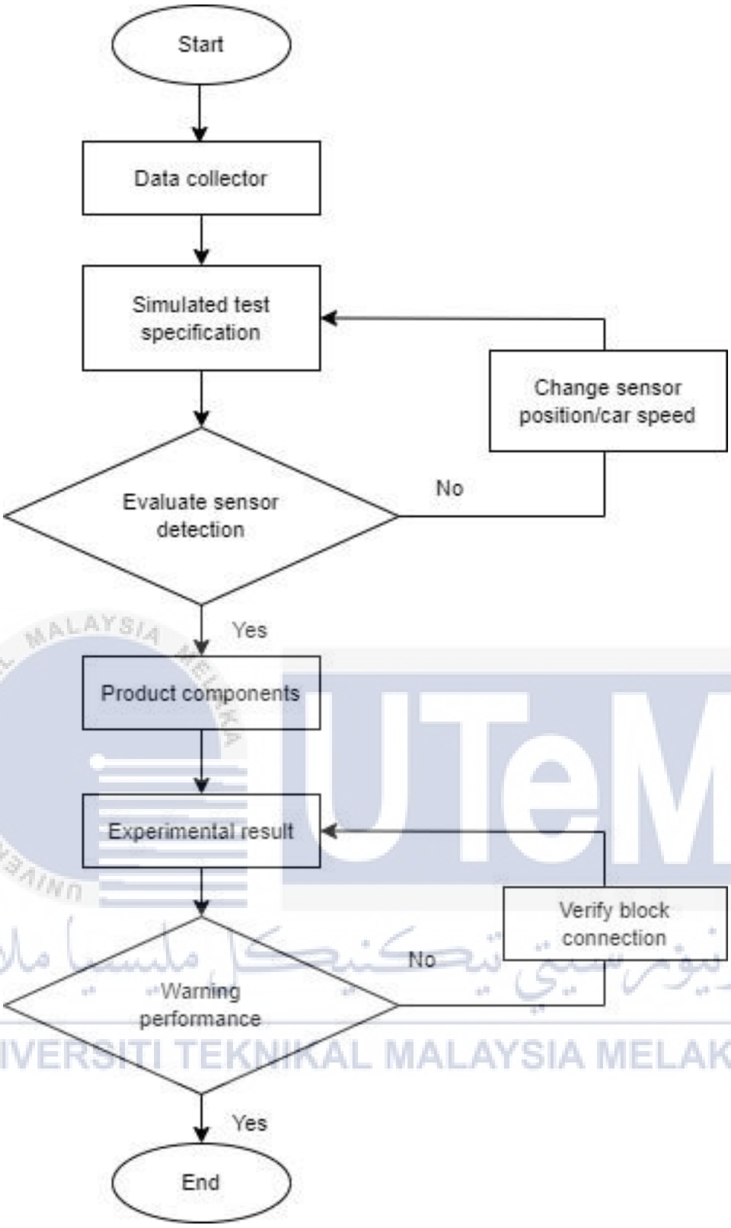


Figure 3.1 Flowchart process

3.3 Data collector

The initial step in developing a blind spot detection system is to clearly define the problem it aims to solve. This involves conducting a thorough analysis of accident statistics, understanding driver behavior, and identifying critical blind spot areas that pose significant risks. By gathering data on accident patterns and identifying common scenarios where blind spot detection would be beneficial, the specific requirements and objectives of the system can be established.

Choosing the appropriate sensors is crucial for accurate blind spot detection. Various types of sensors can be utilized, such as ultrasonic sensors, radar, and cameras. Each sensor type has its own advantages and limitations, and the selection depends on factors such as cost, performance, reliability, and environmental conditions. Ultrasonic sensors are suitable for short-range detection, radar provides long-range coverage, and cameras offer visual information for object recognition. The sensor selection process involves evaluating the trade-offs and determining the optimal sensor configuration for the blind spot detection system.

Once the sensors are selected, the system acquires data from these sensors to gather information about the surrounding environment. This may involve capturing sensor readings such as distance measurements, object speed, and relative positions. The data acquisition process should be carefully designed to ensure accurate and timely data retrieval, considering factors like sensor sampling rates, synchronization, and data integrity.

Once the objects are detected and tracked, the blind spot detection system evaluates the risk associated with each object and determines the appropriate response. This stage involves analyzing factors such as the time to collision, relative speed, object trajectory, and the driver's intentions. The system assesses the potential for a collision or unsafe maneuver and makes decisions accordingly. Decision-making algorithms and logic are employed to trigger appropriate alerts or warnings to the driver based on the analyzed information. Based on the analysis of the detected objects and their associated risks, the blind spot detection system generates alerts or warnings to the driver. These alerts are designed to capture the driver's attention and convey the presence of potential hazards in the blind spot.

3.4 Simulated test specification

Based on the TruckSim simulation platform, vehicle's performance characteristics and referring to the parameters of the real vehicle, the blind spot detection system was developed. In order to run this simulation, there are several factors that need to be observed, including the specification of the commercial vehicle, the coordinate of the sensor and the speed of the car. 2-axle truck LCF van was selected for this experiment. The commercial vehicle parameters are shown in Figure 3.2.

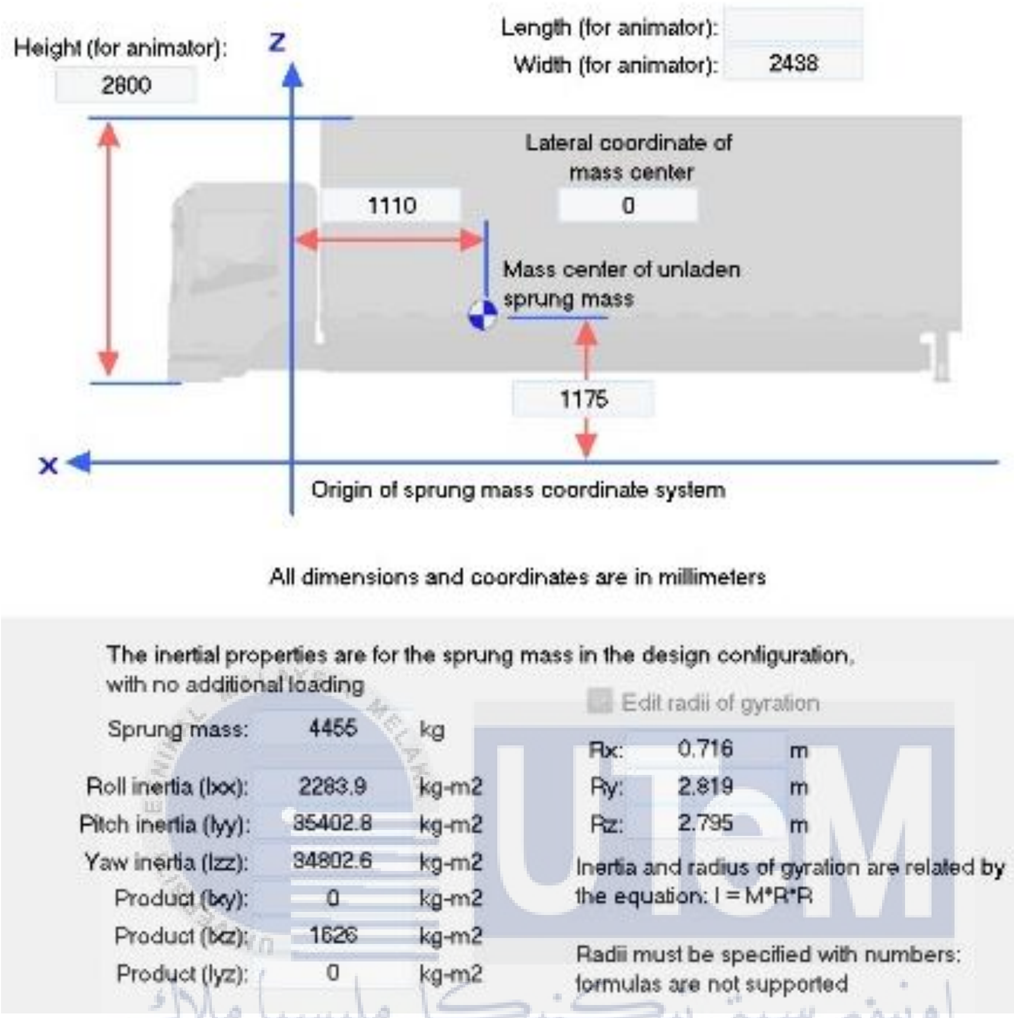


Figure 3.2 LCF van 2-axle truck parameter.

The Figure 3.3 shows the simulated test specification for this experiment. For the first experiment, trucks will travel at constant speed 90 kmph and cars will overtake the blind spot at a speed of 110 kmph. Both of these vehicles move according to the speed limit set on the highway. For the second experiment, response time is measured when the car moves through the blind zone while the truck is in a static condition. The car will move at 30 kmph, 50 kmph and 70 kmph at constant speed. 3 different coordinates of the sensor was set in table below to identify the best position and give an early warning to the driver. The angle for the sensor is set at 30° according to the sensitivity of the ultrasonic sensor. If the car will approach the truck under a distance of 4 meter and in an angle of 30°, the sensor will give a signal data.

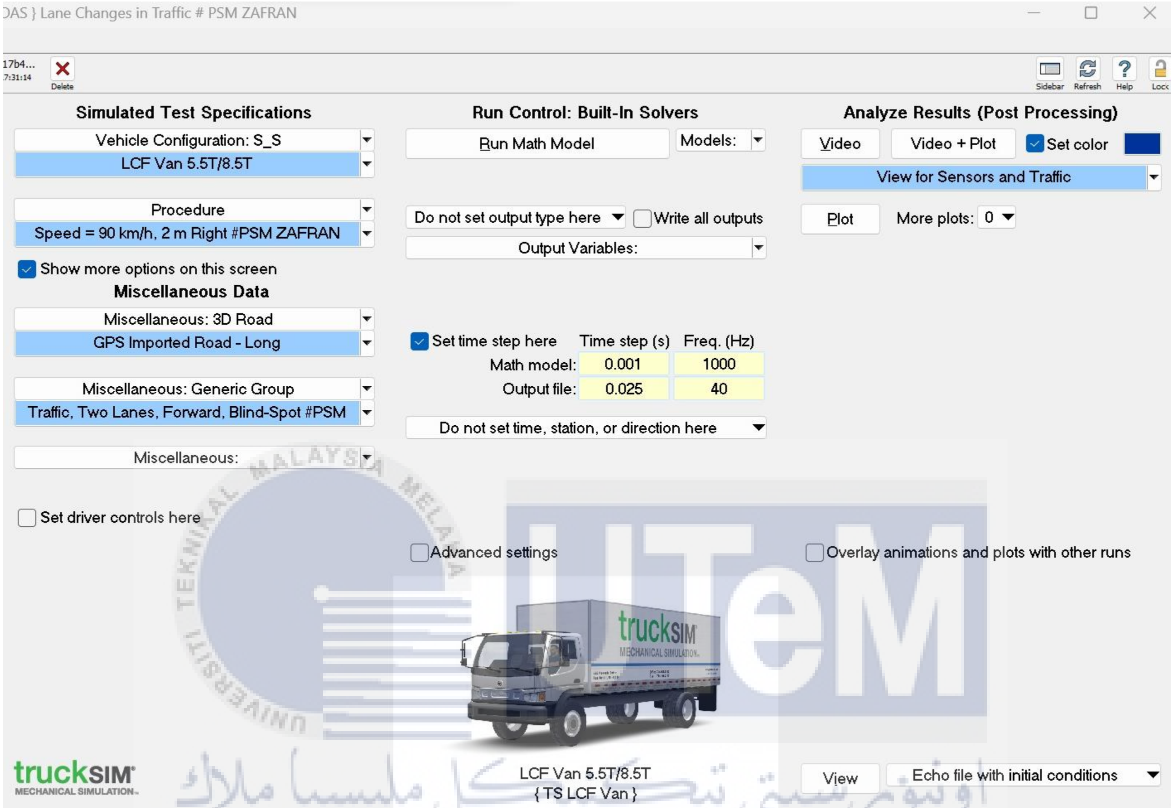


Figure 3.3 Lateral detection condition

3.5 Evaluate sensor detection

Once the sensor angles and coordinates are set, the model can be run for each experiment. Based on the simulation video, a picture of the incident situation can be seen according to the information that entered into the parameters. The Figure 3.4 shows position 1 is close to the driver and the front tire which is -2000 mm coordinate of sensor in sprung-mass coordinate system. The Figure 3.5 shows that the second position is in the middle close to the rear tire, -4500 mm coordinate of sensor in sprung-mass coordinate system. The Figure 3.6 shows the third position which is placed at the end of the body truck -7000 mm coordinate of sensor in sprung-mass coordinate system. The Figure 3.7 below shows some of the data sources that can get from the data manager. Three data taken to determine a good position based on time response. The sensor signal that will be detected on the car will show a value of 1 while if there is no 0. The angle (°) of the car will be taken according to the sensitivity of the ultrasonic sensor as well as the distance of the car from the sensor (m) which is parallel to the time (t) and the sensor signal. All this data will be recorded in Microsoft excel.

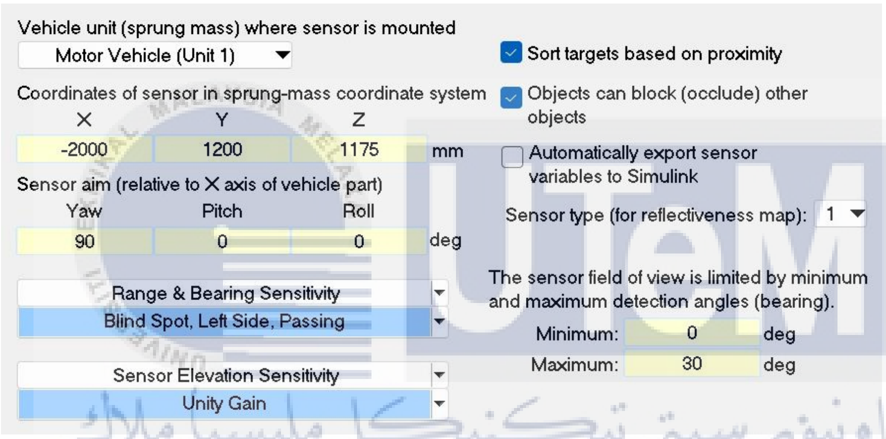


Figure 3.4 Position 1 coordinate.

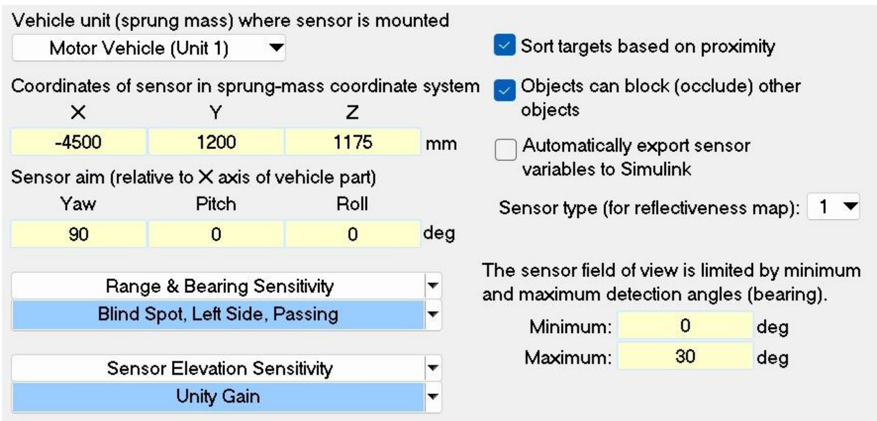


Figure 3.5 Position 2 coordinate.

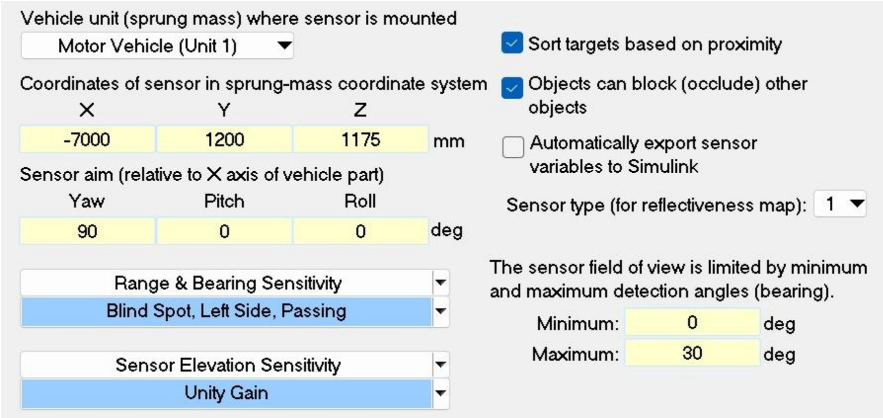


Figure 3.6 Position 3 coordinate.

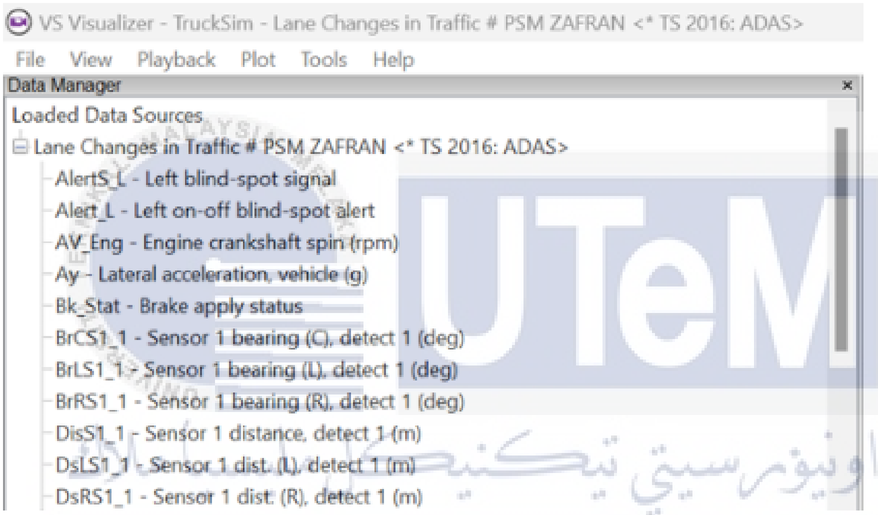


Figure 3.7 Loaded Data Sources TruckSim.

The software tools TruckSim allow to simulate trucks. Additional software, like Simulink, can be used to augment core models. The data recorded in excel will be entered in the workspace as shown in the diagram below. The Figure 3.8 below shows the From Workspace block is used to load initial data or parameters from the MATLAB workspace into the model. This can contain the information required for the initialization or configuration of commercial vehicle blind spot detection.

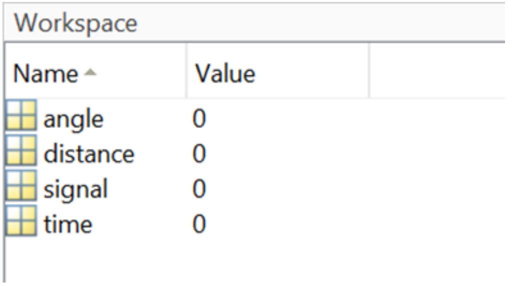


Figure 3.8 Workspace simulink.

The Figure 3.9 shows the block diagram for this simulation. The If block represents a conditional structure where the logic in it will determine the execution path based on a certain condition. This condition can be related to whether there is a vehicle in the blind spot or not. The If Action Subsystem block is likely a subsystem that contains logic or actions that are taken if the conditions from the "If" block are met. This can include the process of detecting vehicles in the blind spot or taking preventive measures. The Merge block is used to combine different execution paths. After the action or logic is executed in the "If Action Subsystem" block, the result is then merged back into the main line. The Scope block enables monitoring and visualization of signals or data during simulation. In the context of blind spot detection, this block may be used to monitor the results of the detection process, such as the position of the vehicle detected in the blind spot.

The Time block provides time information for the simulation, allowing the position of vehicles to change over time. The To Workspace block is used to save data or signals from the model to the MATLAB workspace. This facilitates the analysis of simulation results after the simulation is complete. When all these blocks are combined, the Software-In-Loop (SIL) model creates a logical control flow that enables the simulation of commercial vehicle blind spot detection in the MATLAB Simulink environment.

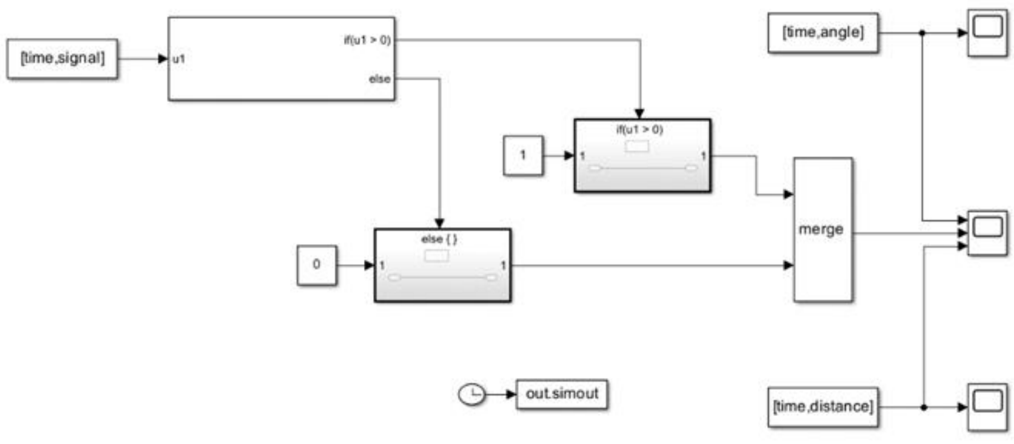


Figure 3.9 Software-In-Loop (SIL)

Block Diagram.

3.6 Product components

3.6.1 Arduino Due

The Arduino Due distinguishes itself within the Arduino family as it employs an ARM Cortex-M3 ATMEL SAM3X8E microcontroller. Notably, its clock speed can reach 84 MHz, offering superior performance compared to other Arduino models. The integration of the ARM Cortex-M3 microcontroller enhances processing speed and efficiency, making the Arduino Due well-suited for applications requiring high performance. A significant advantage lies in its substantial memory capacity, featuring 512 KB of Flash memory for program storage, 96 KB of RAM for variable data, and support for EEPROM storage, providing ample space for projects with extensive data requirements.

Additionally, this board boasts an increased number of digital and analog input/output pins compared to most other Arduino models. Furthermore, it includes a PWM pin, enabling precise control over analog signal intensity and enhancing project flexibility, particularly in applications involving motor control or other electronic devices.

Figure 3.10 Arduino Due

People that are interested in electronics have a growing following on the Arduino platform(Mellis et al., 2007). Unlike the most previous circuit boards, you can upload new code to the Arduino board with just a USB cable that doesn't required any additional hardware. The software for the Arduino makes programming easier to learn by using a simplified version of C++.

3.6.2 Ultrasonic Sensor

The sensor comprises a sender that emits ultrasonic waves, a recipient that detects the echo, and supporting nodes for the regular functioning of the module. As illustrated in Figure 3.11, the HC-SR04 ultrasonic rangefinder is depicted with 'T' and 'R' denoting the transmitter and receiver, respectively. The rangefinder produces sound waves with a frequency of 40 kHz. It gathers information about the time taken for the sound waves to travel from the sensor to the object and back. These sound waves are emitted, bounce off the object, and return to the receiver as detailed in Figure. The ultrasonic signal is emitted at a 30-degree angle, as illustrated in Figure 3.12 (Zhmud et al., 2018).

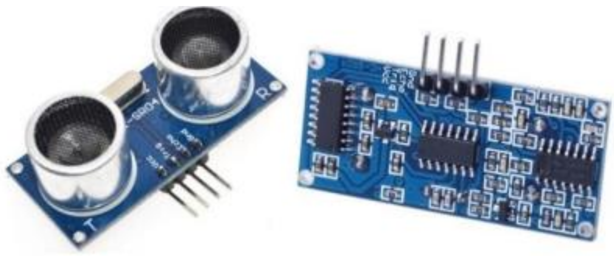


Figure 3.11 Ultrasound rangefinder HC-SR04 **(Zhmud et al., 2018)**

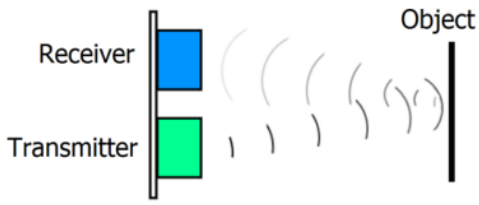


Figure 3.12 Movement of the ultrasonic signal from the transmitter to the receiver **(Zhmud et al., 2018)**

The wave that transmits the ultrasonic signal is pointed at a 30° angle. (Zhmud et al., 2018) Figure 3.13 shows the direction of propagation of the ultrasonic signal from the transmitter. The optimum measurement angle is 15°. Unlike infrared sensors, the measurements of ultrasonic range finders are unaffected by sunlight or the colour of objects.

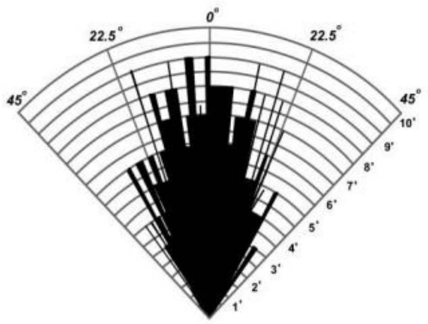


Figure 3.13 The ultrasonic wave pattern **(Zhmud et al., 2018)**.

3.6.3 LED

A light-emitting diode (LED) is a semiconductor device that produces light as a result of the passage of an electric current. Within the semiconductor material, electrons and holes, the charge carriers, combine, leading to the emission of light. Various colors of light are generated by employing different semiconductor materials with distinct bandgaps.

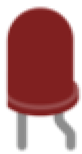


Figure 3.14 LED

3.6.4 Buzzer

A device known as a buzzer is employed to generate tones, alerts, or sounds. Characterized by a straightforward design, lightweight nature, and affordability, it proves to be efficient and can be constructed in diverse sizes, operating across a spectrum of frequencies to produce a range of sound outputs.

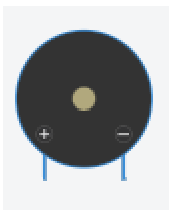


Figure 3.15 Buzzer.

3.7 Experimental result

The Ultrasonic Sensor in the model serves as the input, detecting obstacles within the blind spot. The If Block functions as a conditional statement, examining the sensor data to determine whether the vehicle is present. The If Action Subsystem encapsulates the logic that dictates the system's response when a potential obstacle is identified. This may include activation of warning signals. The commercial vehicle replica employed operates on a 1:16 scale, with its sensor designed to identify vehicles measuring less than 125 cm, in accordance with the scale of commercial vehicle replicas. The measurement value of the distance between the vehicle and the sensor is taken from the TruckSim simulation results.

The Merge Block likely integrates various pathways or conditions within the system, enabling a unified response to different scenarios. Data Type Conversion Blocks ensure consistency in data formats between different elements of the system, facilitating seamless information exchange. The Gain Block adjusts signal magnitudes, aiding in fine-tuning the system's sensitivity or responsiveness. The Digital Output Block signifies the system's response, translating the processed information into actionable commands. This could involve sending signals to actuators responsible for triggering warnings, such as lights and buzzer, providing real-time feedback about detected blind spot vehicles.

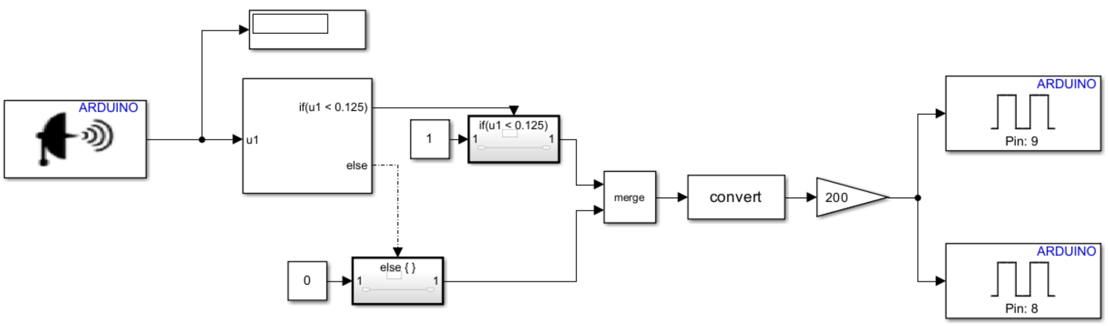


Figure 3.16 Hardware-In-Loop (HIL)

Block Diagram.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The Results and Discussion section of this report presents the findings of the research on the development of a blind spot detection system for commercial vehicle. The system employs an ultrasonic sensor, Arduino Due microcomputer, LED and buzzer to detect vehicles within the blind spot of a truck and give early warning to the driver when the car overtake the truck based on the optimum position of the sensor. This section covers the results of the simulation, including time response, signal, angle of sensor, and distance.

The distance measurement experiments are conducted by placing objects at different distances from the ultrasonic sensor. The Arduino microcontroller processes the signal received from the sensor and displays the calculated distance on the connected display module. As a result, the ultrasonic sensor exhibited reliable and accurate distance measurements within the specified range. The ability of ultrasonic sensors has been explored to detect obstacles by providing a simple obstacle detection circuit. The Arduino microcontroller reacts immediately to the signal received from the sensor and provides the appropriate output.

4.2 Results and analysis data

To get the optimal sensor position, time response is the main reference. In addition, the angle and distance of the car from the sensor is also taken to ensure that this simulation is performed according to the specifications of the ultrasonic sensor. The position of the truck driver in this simulation is on the left side, the car overtake the truck from the left lane. This data will be taken from 3 sensor positions with different coordinates. The Figures below shows the simulation results of 3 sensor positions. The front left side of the car is the first part that the sensor will detect. The sensor will only detect and send a signal if the car is between an angle of 30° and below a distance of 4 meters from the sensor. This simulation data is obtained from TruckSim.

Figure 4.1 Sensor placement at position 1.

Figure 4.2 Sensor placement at position 2.

Figure 4.3 Sensor placement at position 3.

4.2.1 Static test

The tables below shows the results of simulation experiments from TruckSim. For the first experiment, the car traveled at constant speeds of 30 kmph, 50 kmph and 70 kmh. For a car speed of 30 kmph, position 3 is the position of the sensor that gives a fast response time compared to the others, which is as early as 2.975 seconds at an angle of 30° with a distance of 1.96 meters from the sensor. Followed by position 2 with 3.275 seconds and position 1 with 3.575 seconds. The angle and distance of the car from the sensor for all positions is approximately the same. At a constant speed of 50 kmph, position 1 gives a slow reaction compared to all with only 2.23 seconds followed by position 2 2.03 seconds and position 3 1.85 seconds. When the car is moving at constant speed 70 kmph, position 3 still provides a quick response with a distance of 1.87 meters as early as 1.38 seconds. Unlike other car speeds, the sensor detects reactions with different angles and distances. This is because the speed of the car affects the time response signal on the sensor. The graph below shows the output from the Simulink model Block resulting from the data from the TruckSim simulation. At a constant speed of 30 kmph the period of time the car passes in the sensor area is 0.35 seconds, 50 kmph 0.125 seconds and 70 kmph with 0.025 seconds.

Table 4.1 Car moving with a constant speed of 30 kmph at Position 1.

Time (s)	Signal	Angle (°)	Distance (m)
3.575	1	30	1.963377
3.6	1	30	1.963374
3.625	1	30	1.963635
3.65	1	30	1.964285
3.675	1	30	1.964967
3.7	1	30	1.965678
3.725	1	30	1.966415
3.75	1	30	1.967177
3.775	1	30	1.96796
3.8	1	30	1.968762
3.825	1	30	1.969579
3.85	1	25.23331	1.886058
3.875	1	19.3244	1.808309
3.9	1	12.95907	1.751317
3.925	1	6.254102	1.717158

Table 4.2 Car moving with a constant speed of 30 kmph at Position 2.

Time (s)	Signal	Angle (°)	Distance (m)
3.275	1	30	1.962728
3.3	1	30	1.962724
3.325	1	30	1.962721
3.35	1	30	1.962716
3.375	1	30	1.962711
3.4	1	30	1.962706
3.425	1	30	1.962701
3.45	1	30	1.962696
3.475	1	30	1.962691
3.5	1	30	1.962687
3.525	1	29.83717	1.959426
3.55	1	24.3631	1.865895
3.575	1	18.37189	1.791071
3.6	1	11.93487	1.737385
3.625	1	5.173928	1.707215

Table 4.3 Car moving with a constant speed of 30 kmph at position 3.

Time (s)	Signal	Angle (°)	Distance (m)
2.975	1	30	1.962083
3	1	30	1.962085
3.025	1	30	1.962085
3.05	1	30	1.962084
3.075	1	30	1.962082
3.1	1	30	1.96208
3.125	1	30	1.962077
3.15	1	30	1.962074
3.175	1	30	1.962071
3.2	1	30	1.962068
3.225	1	28.82552	1.939487
3.25	1	23.25504	1.849471
3.275	1	17.17813	1.7786
3.3	1	10.67619	1.729236
3.325	1	3.884593	1.70326

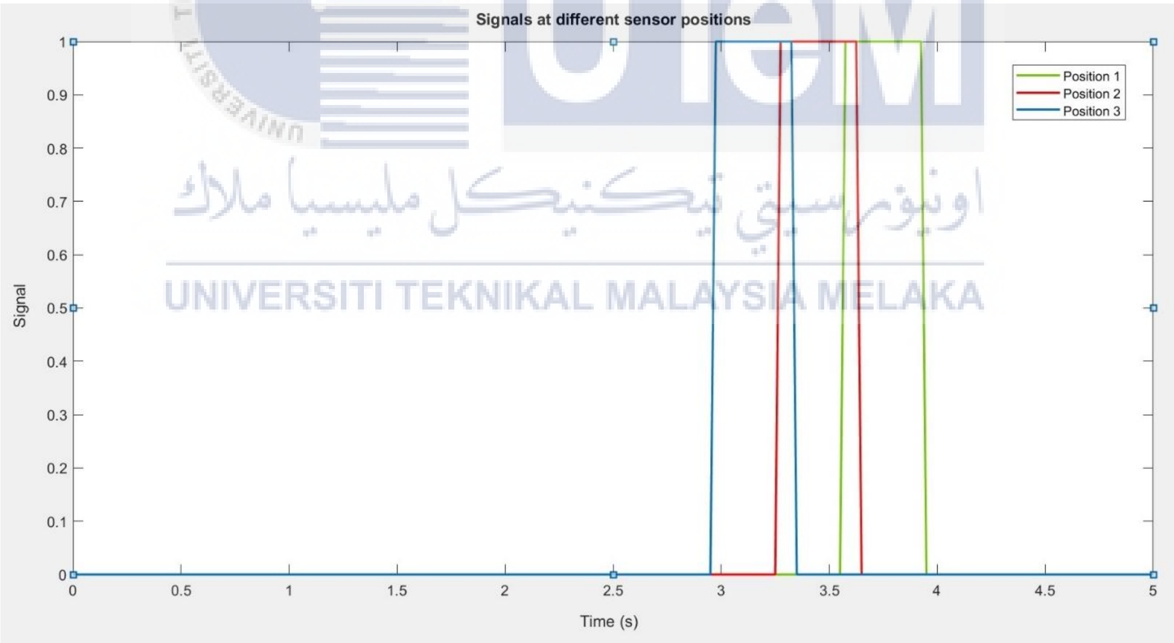


Figure 4.4 Signal-Time graph at a constant speed of 30 kmph.

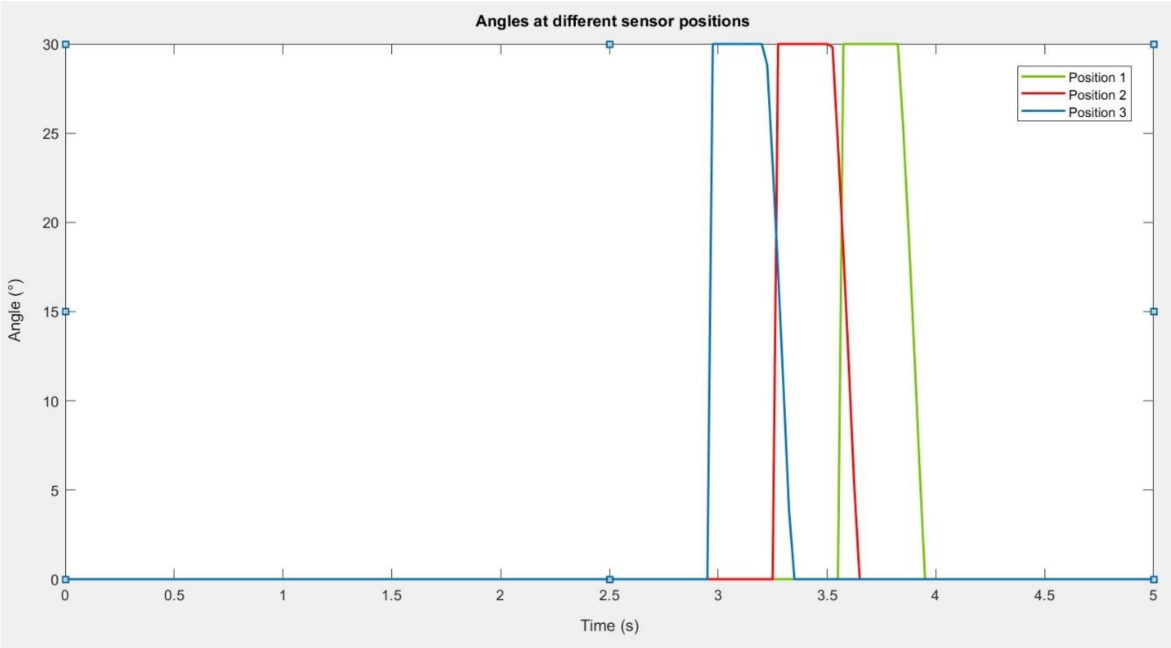


Figure 4.5 Angle-Time graph at a constant speed of 30 kmph.

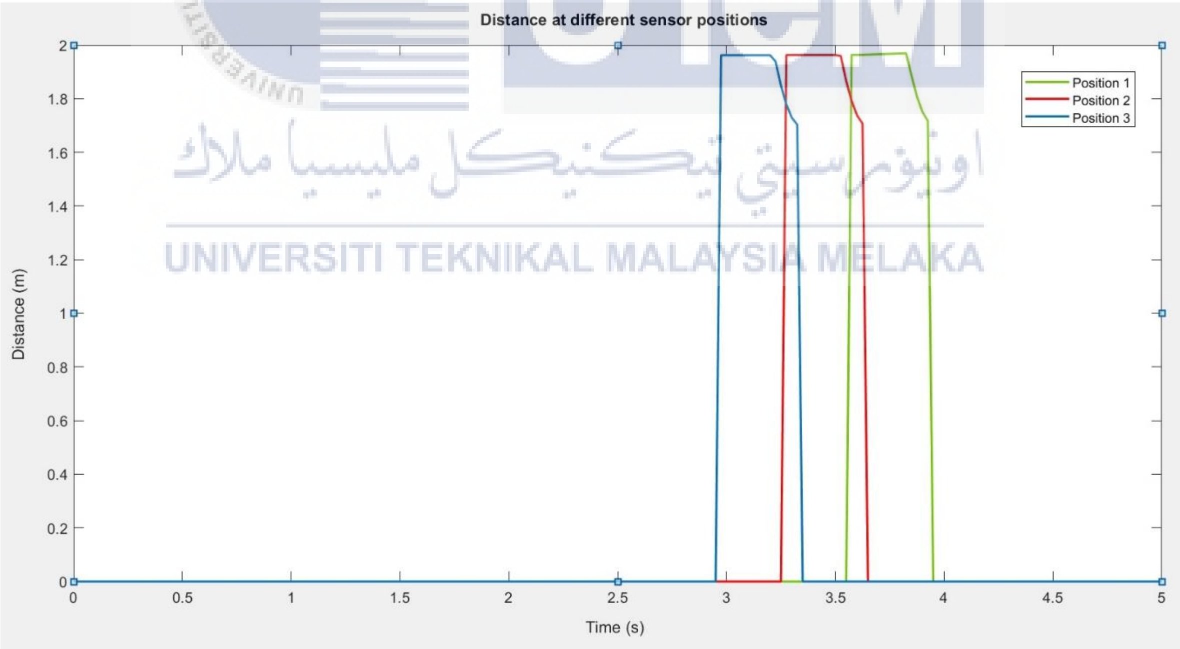


Figure 4.6 Distance-Time graph at a constant speed of 30 kmph.

Table 4.4 Car moving with a constant speed of 50 kmph.

POSITION 1			
Time (s)	Signal	Angle (°)	Distance (m)
2.225	1	30	1.965865
2.25	1	30	1.967171
2.275	1	30	1.968519
2.3	1	26.44347	1.905061
2.325	1	16.53418	1.779947
2.35	1	5.512741	1.714711
POSITION 2			
Time (s)	Time (s)	Time (s)	Time (s)
2.025	1	30	1.962616
2.05	1	30	1.962604
2.075	1	30	1.962608
2.1	1	30	1.962625
2.125	1	23.52526	1.85379
2.15	1	13.19609	1.745914
POSITION 3			
Time (s)	Signal	Angle (°)	Distance (m)
1.85	1	30	1.962565
1.875	1	30	1.962562
1.9	1	30	1.962527
1.925	1	29.72011	1.956928
1.95	1	20.30947	1.812139
1.975	1	9.6104	1.723647

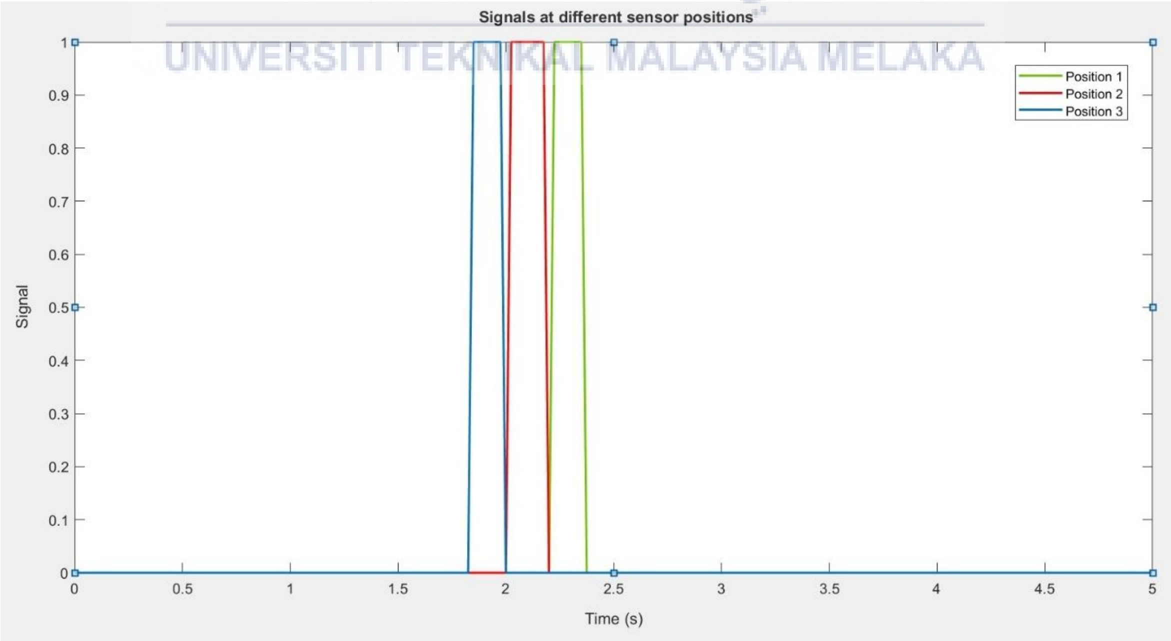


Figure 4.7 Signal-Time graph at a constant speed of 50 kmph.

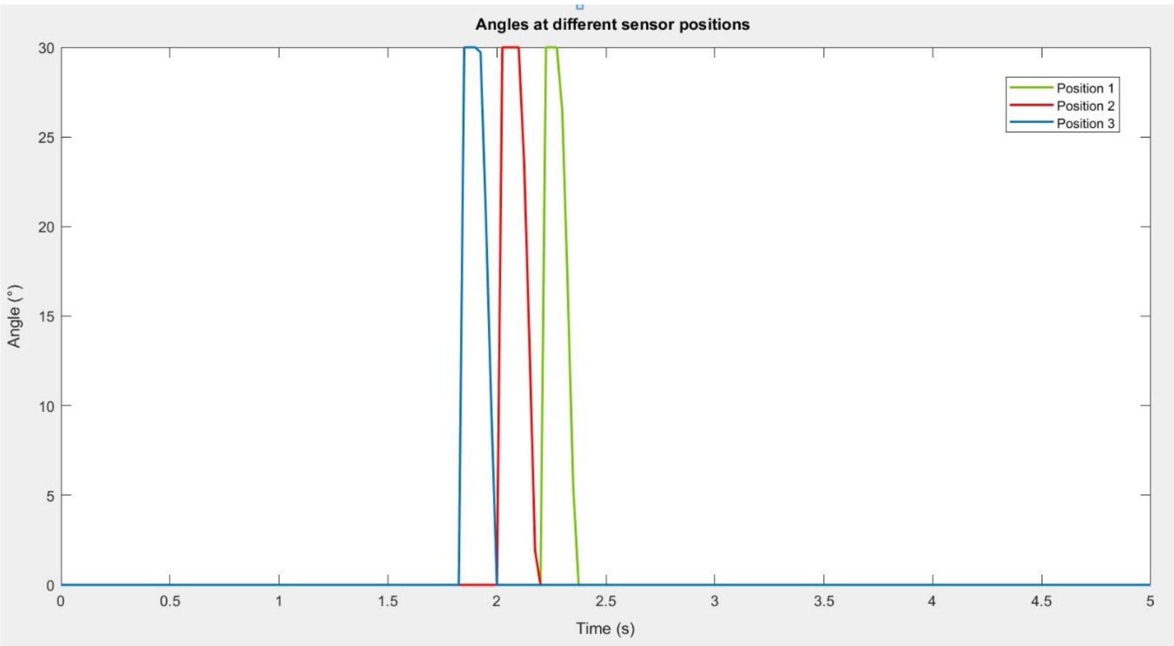


Figure 4.8 Angle-Time graph at a constant speed of 50 kmph.

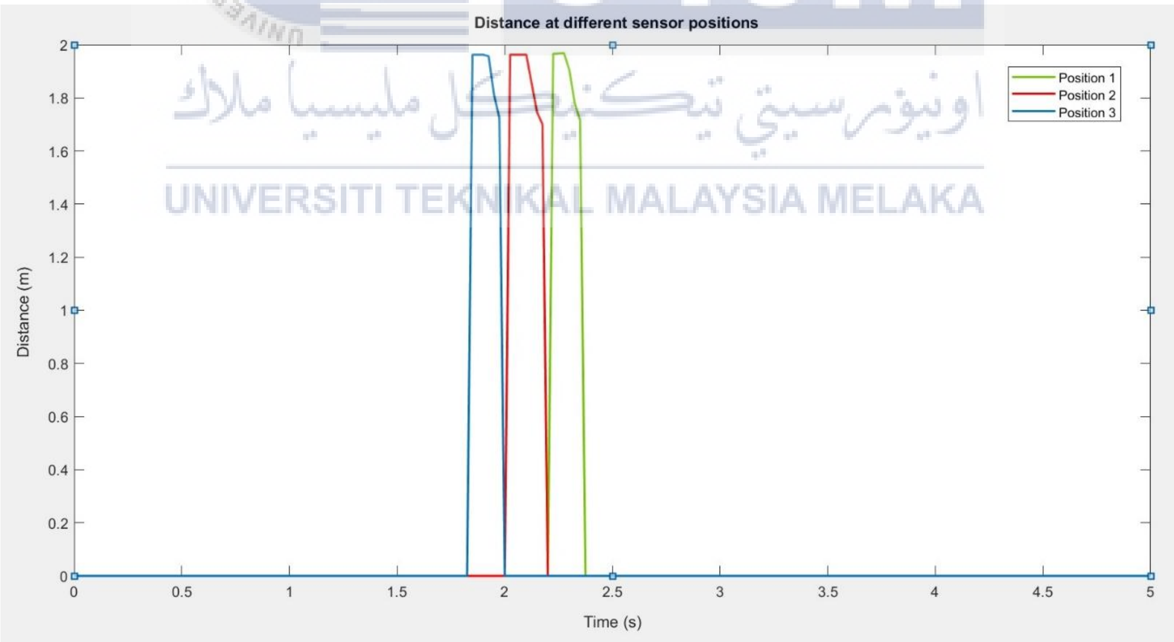


Figure 4.9 Distance-Time graph at a constant speed of 50 kmph.

Table 4.5 Car moving with a constant speed of 70 kmph.

POSITION 1			
Time (s)	Signal	Angle (°)	Distance (m)
1.625	1	29.44751	1.9581
1.65	1	15.75192	1.772674
POSITION 2			
Time (s)	Time (s)	Time (s)	Time (s)
1.5	1	27.06472	1.9088
1.525	1	12.84742	1.74346
POSITION 3			
Time (s)	Signal	Angle (°)	Distance (m)
1.375	1	24.43891	1.866871
1.4	1	9.735416	1.72449

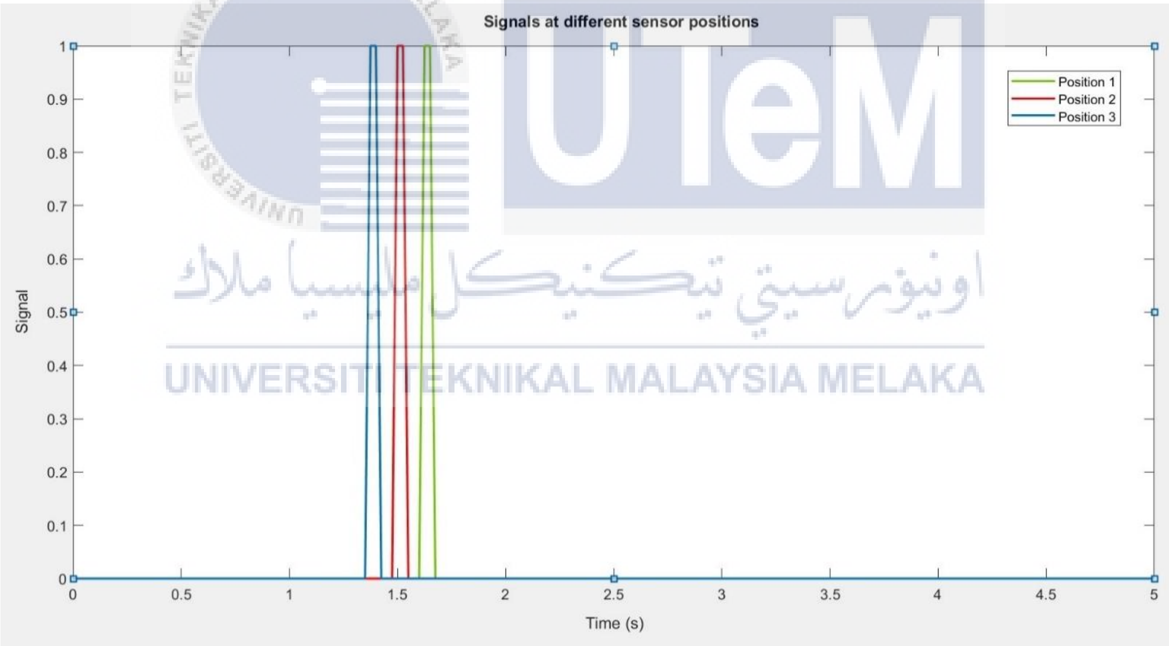


Figure 4.10 Signal-Time graph at a constant speed of 70 kmph.

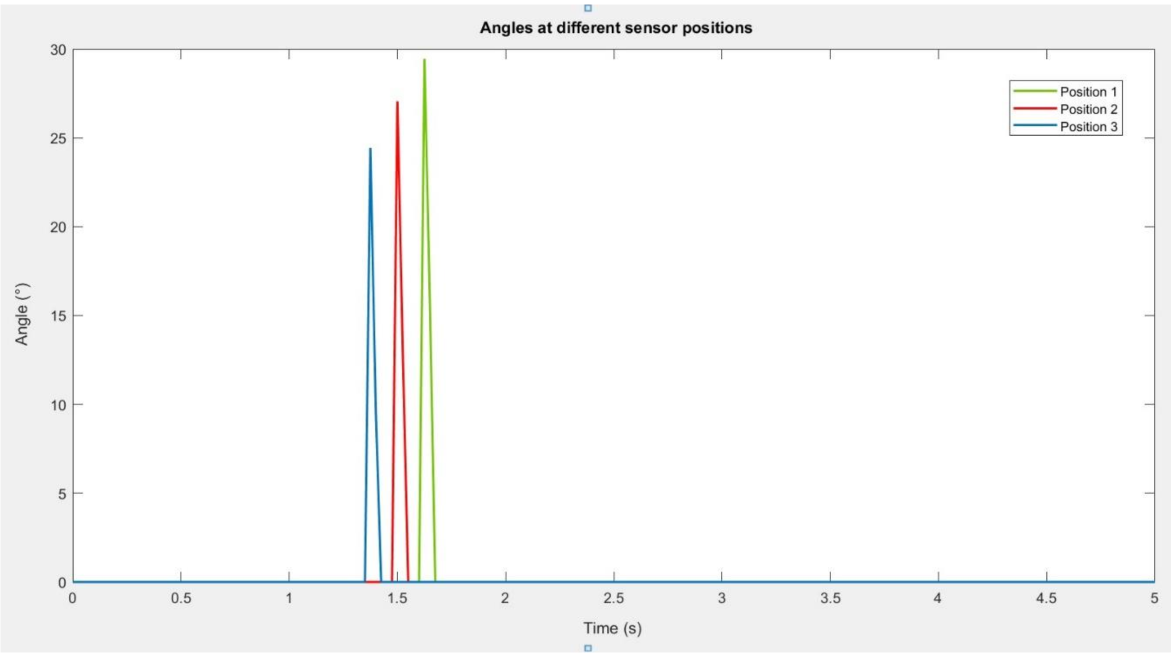


Figure 4.11 Angle-Time graph at a constant speed of 70 kmph.

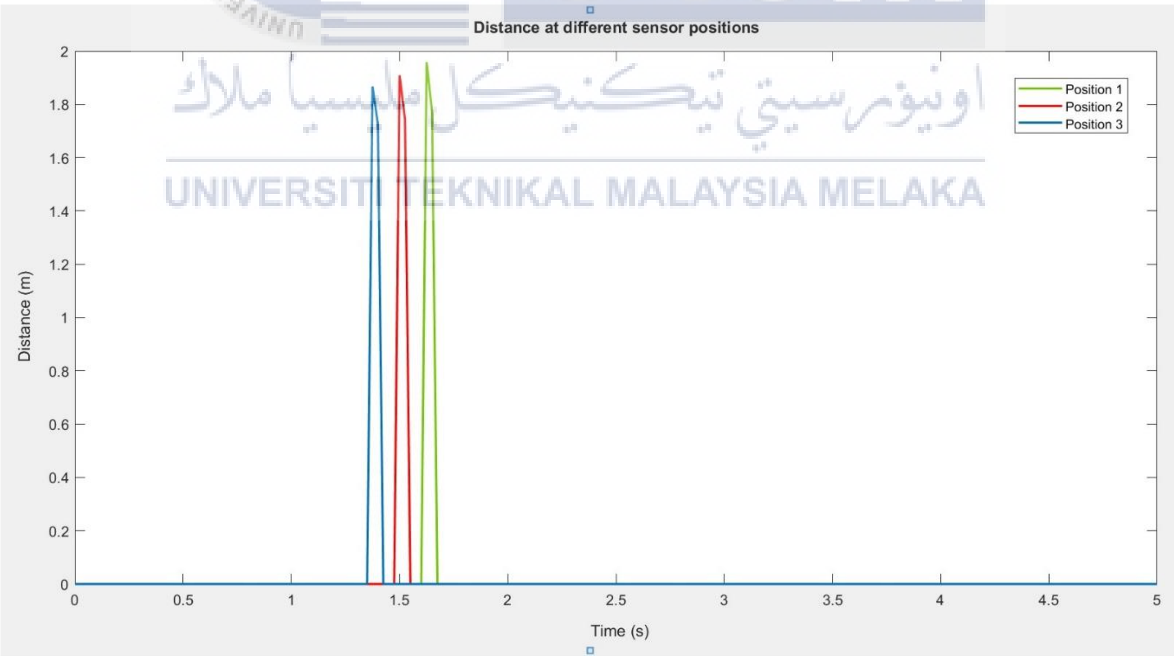


Figure 4.12 Distance-Time graph at a constant speed of 70 kmph.

4.2.2 Dynamic test

The table below shows the results of the simulation from experiment 2. The truck will move at a constant speed of 90 kmph while the car moves at a constant speed of 110 kmh. The results of the TruckSim simulation show that position 3 provides a good response time as early as 3.85 seconds at a distance of 1.97 meters. Position 2 with 4.3 seconds and position 1 with 4.75 seconds. The closest distance a car passes in the sensor area is 1.71 meters. The graph below shows the output from the Simulink model Block resulting from the data from the TruckSim simulation. The duration of the car passing in the sensor Area is for 1 second.

Table 4.6 Car moving at a constant speed of 110 kmph at Position 1.

Time (s)	Signal	Angle (°)	Distance (m)
4.75	1	30	1.966135
4.775	1	30	1.966143
4.8	1	30	1.966148
4.825	1	30	1.966151
4.85	1	30	1.966149
4.875	1	30	1.966144
4.9	1	30	1.966134
4.925	1	30	1.966118
4.95	1	30	1.966097
4.975	1	30	1.966069
5	1	30	1.966034
5.025	1	30	1.965991
5.05	1	30	1.965939
5.075	1	30	1.965878
5.1	1	30	1.965807
5.125	1	30	1.965725
5.15	1	30	1.965632
5.175	1	30	1.965527
5.2	1	30	1.965408
5.225	1	30	1.965276
5.25	1	30	1.9651
5.275	1	30	1.964741
5.3	1	30	1.964415
5.325	1	30	1.964118
5.35	1	30	1.963852
5.375	1	30	1.963614
5.4	1	30	1.963403
5.425	1	30	1.963219
5.45	1	30	1.963061
5.475	1	30	1.962927
5.5	1	30	1.962818
5.525	1	30	1.96273
5.55	1	30	1.962665
5.575	1	30	1.96262
5.6	1	28.46309	1.933305
5.625	1	24.70329	1.870843
5.65	1	20.70211	1.816984
5.675	1	16.47831	1.772513
5.7	1	12.06236	1.738149
5.725	1	7.496511	1.7145
5.75	1	2.83338	1.70201

Table 4.7 Car moving at a constant speed of 110 kmph at Position 2.

Time (s)	Signal	Angle (°)	Distance (m)
4.3	1	30	1.965101
4.325	1	30	1.965126
4.35	1	30	1.965149
4.375	1	30	1.965172
4.4	1	30	1.965193
4.425	1	30	1.965213
4.45	1	30	1.965233
4.475	1	30	1.965252
4.5	1	30	1.96527
4.525	1	30	1.965289
4.55	1	30	1.965307
4.575	1	30	1.965325
4.6	1	30	1.965343
4.625	1	30	1.965362
4.65	1	30	1.965381
4.675	1	30	1.9654
4.7	1	30	1.96542
4.725	1	30	1.96544
4.75	1	30	1.965462
4.775	1	30	1.965484
4.8	1	30	1.965506
4.825	1	30	1.96553
4.85	1	30	1.965554
4.875	1	30	1.965578
4.9	1	30	1.965602
4.925	1	30	1.965626
4.95	1	30	1.96565
4.975	1	30	1.965673
5	1	30	1.965695
5.025	1	30	1.965715
5.05	1	30	1.965733
5.075	1	30	1.965749
5.1	1	30	1.965761
5.125	1	30	1.96577
5.15	1	28.717	1.941113
5.175	1	24.98112	1.878045
5.2	1	21.00395	1.823476
5.225	1	16.80313	1.778189
5.25	1	12.40843	1.742864
5.275	1	7.863322	1.717898
5.3	1	3.214136	1.704061

Table 4.8 Car moving at a constant speed of 110 kmph at Position 3.

Time (s)	Signal	Angle (°)	Distance (m)
3.85	1	30	1.974787
3.875	1	30	1.963807
3.9	1	30	1.963877
3.925	1	30	1.963941
3.95	1	30	1.964001
3.975	1	30	1.964056
4	1	30	1.964106
4.025	1	30	1.964151
4.05	1	30	1.964192
4.075	1	30	1.964229
4.1	1	30	1.964262
4.125	1	30	1.964291
4.15	1	30	1.964317
4.175	1	30	1.964339
4.2	1	30	1.964358
4.225	1	30	1.964375
4.25	1	30	1.964389
4.275	1	30	1.964402
4.3	1	30	1.964413
4.325	1	30	1.964422
4.35	1	30	1.964431
4.375	1	30	1.964439
4.4	1	30	1.964447
4.425	1	30	1.964456
4.45	1	30	1.964465
4.475	1	30	1.964475
4.5	1	30	1.964486
4.525	1	30	1.964498
4.55	1	30	1.964513
4.575	1	30	1.964529
4.6	1	30	1.964548
4.625	1	30	1.964571
4.65	1	30	1.964596
4.675	1	30	1.964624
4.7	1	29.01862	1.945669
4.725	1	25.30143	1.882019
4.75	1	21.342	1.826824
4.775	1	17.15726	1.780869
4.8	1	12.7756	1.744886
4.825	1	8.237193	1.719499
4.85	1	3.592833	1.705182

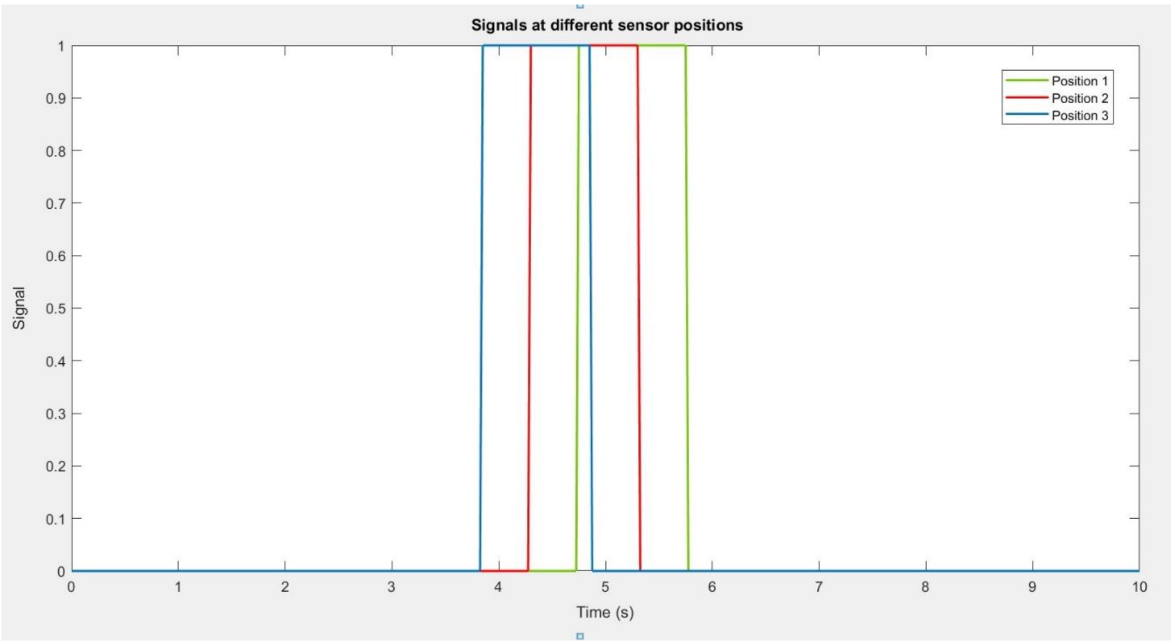


Figure 4.13 Signal-Time graph at a constant speed of 110 kmph.

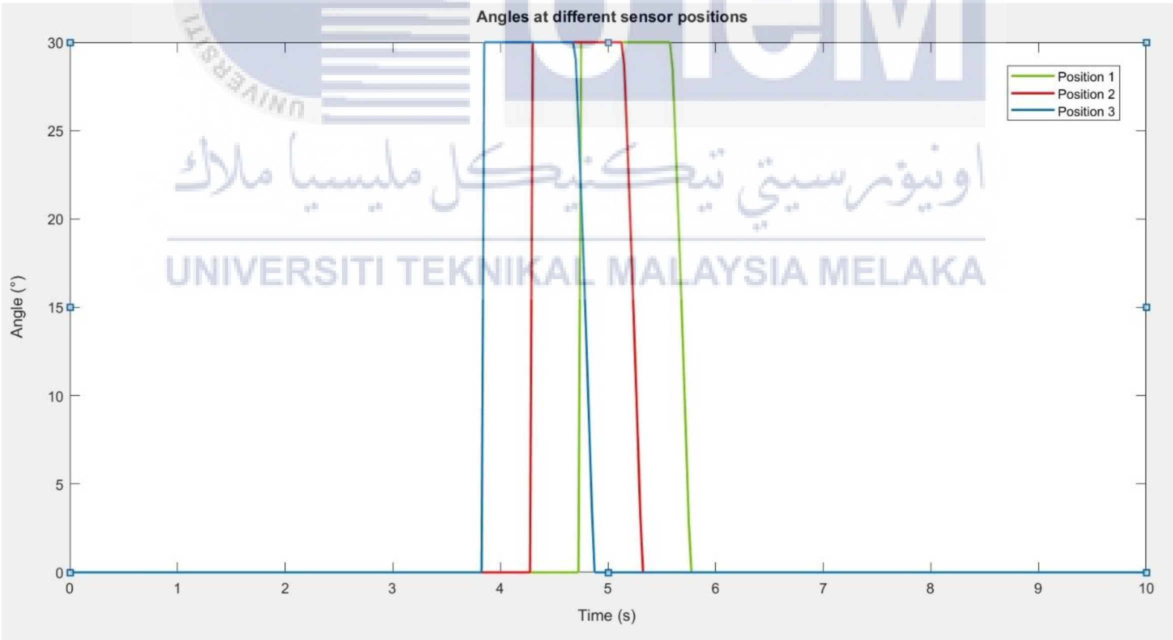


Figure 4.14 Angle-Time graph at a constant speed of 110 kmph.

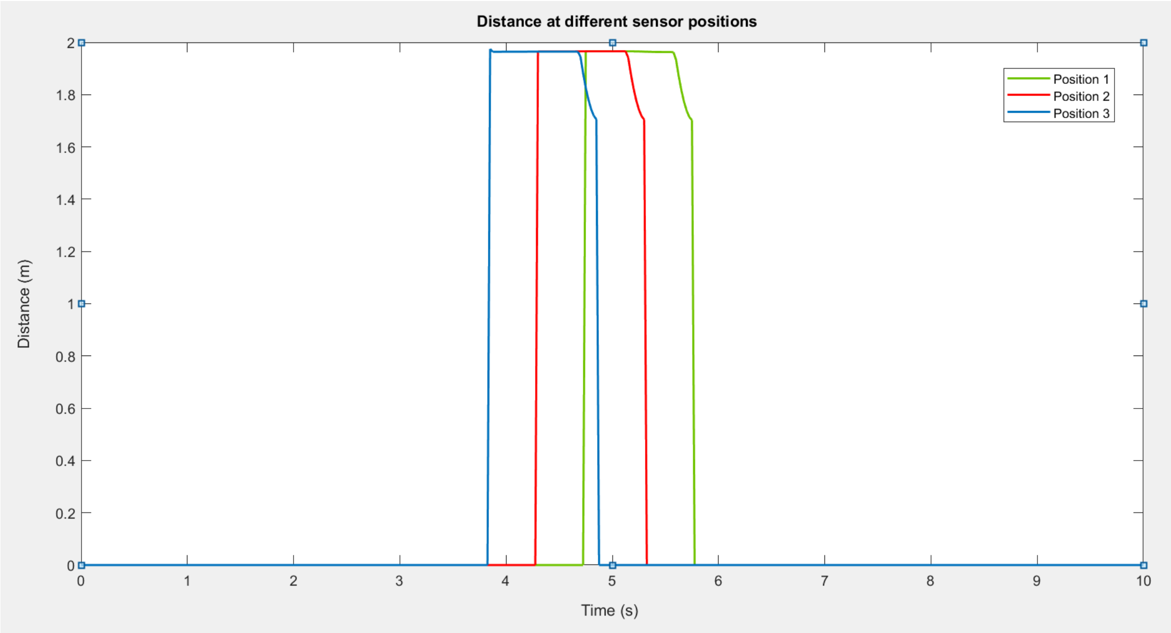


Figure 4.15 Distance-Time graph at a contant speed of 110 kmph.

4.3 Hardware

Simulink model blocks are used to represent physical components such as ultrasonic sensors, LEDs, and buzzers. The commercial vehicle replica used is 1:16 scale. Arduino block added and connected to the Arduino Due, including blocks to control the pins on the Arduino. Sensors and actuators, such as ultrasonic, LED, and buzzer connected to the system. The physical connection is determined between Arduino Due, sensor, LED, buzzer, and other components using jumpers. After making sure the Simulink model works properly, the model to the Arduino Due implemented and physically replicated the truck. The position of the ultrasonic sensor on the RC truck is according to the results of the simulation data on TruckSim, which is the end of the vehicle body near the rear tire of the truck. Conducted comprehensive testing to verify the proper functionality of LED, buzzer, and sensor, ensuring the truck replica accurately responded to Simulink commands. Employed Simulink's monitoring tool to real-time monitor sensor data and control signals, making adjustments to optimize parameters when required.

Figure 4.16 Hardware installation into the RC truck.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The objective of this project is to determine the optimal position of the sensor to give an early warning to the driver as well as to identify the configuration of blind spot detection system for commercial vehicle. To identify the sensor position, TruckSim software and MATLAB Simulink were used to conduct the experiment. Objectives of this project has been achieved from the analysis data based on the time response provided from the sensor. Simulation TruckSim and MATLAB Simulink help a lot in developing blind spot detection system for commercial vehicle.

5.2 Recommendation

For the future recommendation, add more sensor to get accuracy data. With many sensors we can analyze the data accurately and get a better response time to determine the optimal sensor position. In addition, can use the MP3 module as an output to increase the effectiveness of the warning to the driver and wireless to save space and make it easier to plug and play.

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APPENDICES

APPENDIX A Gantt Chart PSM

NO	Project Activities	Plan vs Actual Plan	October					November				December					January	
		Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	PSM BRIEFING	Plan																
		Actual																
2	Chapter 4: Results & Discussion	Plan																
		Actual																
3	Chapter 5: Conclusion	Plan																
		Actual																
4	Poster preparation	Plan								MID-TERM BREAK								
		Actual																
5	Final Improvement	Plan																
		Actual																
6	Report Submission	Plan																
		Actual																
7	Thesis summary	Plan																
		Actual																
8	Final Presentation	Plan																
		Actual																
9	Final Improvement	Plan																
		Actual																

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Tarikh (Date): 31 Januari 2021

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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 ZAFRAN ARIF BIN BEDU ARIFIN (B092010430)
Tajuk Tesis: DEVELOPMENT OF BLIND SPOT DETECTION SYSTEM FOR COMMERCIAL 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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