"I hereby declare that I have read through this report entitle "Vehicle Blind Spot Detection and Warning System" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering."

Signature: ………………………………………

Supervisor's name: ……………………………………………………..

Date: ……………………………………..

VEHICLES BLIND SPOT DETECTION AND WARNING SYSTEM

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A report submitted in partial fulfillment of the requirements for the degree of

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declare that this report entitle "Vehicles Blind Spot Detection and Warning System" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature: ………………………………..

Name: ……………………………………………………………...

Date: ……………………………..

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ABSTRACT

Nowadays, the number of accidents involving motorized vehicles is increasing especially the side collision of the vehicles when the driver attempt to change from one lane to another either to left or right which is due to the carelessness of the driver and unsighted the blind spot. However, the cooperation of technology can overcome this problem. The key element is the ability to detect the incoming vehicle in the blind spot area. However, problems rises when the sensor used for the system only able to cover certain amount of area. The objectives of this project is to develop and implement a device that will warn the driver about the incoming vehicles in the blind spot area by blinking LED and to analyze the system in terms of the range and the position of the sensor used for the system. For the methodology, the main components chosen for the system is an Arduino UNO and SRF04 ultrasonic sensor. The first experiment is to make an analysis on the range measured by the sensor by using different materials that is moving towards the sensor at 2 different speed which is at 10km/h and 30km/h. The second experiment is carried out is to make an analysis on the time response of the system with two different position of the sensor which is above the rear tire and under the side mirror with 45º slant. The third experiment is carried out to analyze the time response of the system with two different position of the sensor which is above the rear tire and under the side mirror with 45º slant with the sensor is moving at certain constant velocity. The result shows that the sensor placement above the rear tire is better than under the side mirror.

ABSTRAK

Pada masa kini, bilangan kemalangan yang melibatkan kenderaan bermotor semakin meningkat terutama perlanggaran sampingan kenderaan apabila cubaan pemandu untuk menukar dari satu lorong yang lain sama ada ke kiri atau ke kanan yang disebabkan oleh kecuaian pemandu dan kawasan yang tidak dapat dilihat. Walau bagaimanapun, kerjasama teknologi dapat mengatasi masalah ini. Elemen utama adalah keupayaan untuk mengesan kenderaan yang masuk di kawasan blind spot. Walau bagaimanapun, masalah timbul apabila sensor yang digunakan untuk sistem ini hanya dapat meliputi kawasan kawasan yang tertentu. Objektif projek ini adalah untuk membina alat yang akan memberi amaran kepada pemandu mengenai kenderaan yang masuk di kawasan kawasan bintik buta dengan LED yang berkelip dan untuk menganalisis sistem dari segi jarak dan kedudukan sensor yang digunakan untuk sistem. Untuk metodologi, komponen utama yang dipilih untuk sistem adalah Arduino UNO dan sensor ultrasonic SRF04. Eksperimen pertama adalah untuk membuat analisis mengenai pelbagai yang diukur oleh sensor dengan menggunakan bahan-bahan yang berbeza yang bergerak ke arah sensor pada 2 kelajuan yang berbeza iaitu pada 10 km / j dan 30km / j. Eksperimen kedua dijalankan adalah untuk membuat analisis kepada sambutan masa sistem dengan dua kedudukan berbeza sensor yang di atas tayar belakang dan di bawah cermin sisi dengan kecondongan 45 º. Ekeperimen ketiga dijalankan untuk menganalisis tindak balas masa sistem dengan dua kedudukan berbeza sensor yang di atas tayar belakang dan di bawah cermin sisi dengan 45 º condong dengan sensor yang sedang bergerak pada halaju malar tertentu. Hasil kajian menunjukkan bahawa penempatan sensor di atas tayar belakang adalah lebih baik daripada di bawah cermin sisi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Motivation

There are a lot of accidents happen between vehicles which is caused by the carelessness of the driver when he or she change from one lane to another. According to the traffic safety facts report of National Highway Traffic Safety Administration, there were more than five million motor vehicle crashes reported occurred in the United States in 2011 [1]. There are three times more likely a driver to involve in an accident when changing lanes compared to continuing driving in the same lane [2]. The average of drivers to change lanes is once every 2.76 miles and this frequency increases in suburban rush hour time [3]. A driver that spend 2 seconds to turn his or her head which is travelling at 70 mph (112.65kmh^{-1})has travelled about 205ft (62.484m) unattended [4]. One out of 25 accidents on the highways in the US today is due to dangerous lane changes and merges which is about 630 thousands collision every year [5]. There are 726 deaths which is caused by collisions due to erroneous attempt of lane change and merging [6]. Therefore, something perhaps a device should be designed, developed and implemented on motor vehicles in order to overcome this problem.

1.2 Problem statement

Human beings are aided with the eyes to see and navigate the surroundings. However, the stereoscopic human vision has its own limit of sight. There are certain areas that can't be seen without moving the head to left or right. The area is so called as the blind spot area. So as the driver in a vehicle, they have their own blind spots which means that the area that is blocked by the part of the body of the vehicle. Therefore, the driver cannot see and know what is happening at the blind spot area.

Changing into another lanes without knowing any information about the situation can be very dangerous. The presence of vehicles in the blind spot area while shifting lanes can cause accidents which also may lead to injuries or death of the driver or the passengers. This is also may due to the drivers usually assumes that there are no vehicle in that area or they think the incoming vehicle may apply brakes to avoid collision. This negative assumption is one of the main cause of accidents.

Thus, normal vehicles nowadays are aided with side mirrors which are mounted on the left and right side of the vehicles to widen the vision of the driver and reduce the blind spot area at the same time. The side mirrors help the driver to know the situation at the blind spot area. However, the side mirror is not able to allow the driver to monitor the blind spot area as it is. Therefore, it is still not enough to ensure the safety of the driver especially during changing and merging into another lane.

In this research, the main design parameter that is to be focused is the area covered by the sensor used. The performance of the sensor is also determined by the position of the sensor.

1.3 Objectives

1. To develop and implement a device that will warn the driver about the incoming vehicles in the blind spot area by blinking LED.
2. To analyze the system in terms of the range and the position of the sensor used for the system.

1.4 Scope

1. The experiment is done for two different position of sensor.
2. The speed of the vehicles are 20kmph, 40kmph and 60kmph only.
3. The sensor is implemented to cover the blind spot region of a sedan car.
4. The experiment is done on vehicles that moving at a constant velocity.
5. The vehicles moving forward in the experiment are not affected by hilly area.

CHAPTER 2

LITERATURE REVIEW

2.1 Background of blind spot detection

This research purpose is to bring intelligence into vehicles by providing the ability of obstacles or objects detection in the blind spot area of the vehicle. Thus, an ultrasonic ranging module with microelectronics, will be designed and prototyped into vehicles. This project will use Arduino microcontroller as the main rather than usual Peripheral Interface Controller (PIC) as Arduino provide s flexible, complete, and easy hardware and software platform unlike PIC.

2.2.1 LaRASideCam

A method that is used to detect the incoming vehicles is by using a camera. A program that detects vehicles in the blind spot are which use video data taken from the side mirror of the vehicle is developed. A camera with 320 x 240, 30 fps resolution is mounted on the left wing of the car. It provides YUV444 color frames but the entire algorithm is based on grayscale images. The program is written in C++ language by using the Ecole des Mines' Camellia image processing library and LaRA perception development of work [7][8]. It was implemented on an embedded system so that its core did not use floating-point, dynamic memory allocation or the C++ standard template library. It complies with the ANSI C++ standard and is tested by using Valgrind software [9]. The implementation on the LaRASideCam is shown as in the figure below:

Figure 1.0: Implementation of LaRASideCam on a Citroen C3 [8].

The algorithm is divided into two parts. The first part of the algorithm is used to detect the characteristics on the front of the vehicles. It then uses Support Vector Machine (SVM) artificial learning. Whereas the second part of the algorithm intends to detect the wheels of the vehicles. The system which uses image processing system can be achieved in several ways such as optical flow analysis and pattern recognition [10, 11, 12]. A common and good way to detect incoming vehicles from rear and front sides is to look for the horizontal edges in the picture [13]. Warping the image to align the horizontal edges of the vehicle with the picture borders is the first method used in LaRASideCam.

Figure 1.1: Picture taken from the left wing mirror camera with the warping region in the red box area [8].

Figure 1.2: An image after being warped [8].

The most overt solution to detect the edges on the picture is by using an operator that selects the horizontal edges only but in practice, all the vehicles do not have equal orientation on the image so that such an operator is too restrictive.

Its first characterization algorithm which its purpose to compute each peak and used to characterized vehicle is not portable to any hardware configuration because its parameters has to rely on many factors such as the resolution of the image and the optic parameters of the video camera. The noise at the edges of the peak may become a great disturbance to the system. The camera itself will become a disturbance to the driver since some space is required to mount the camera on the left or right side of the vehicle.

2.2.2 SideEye: Mobile assistant for blind spot monitoring

This system uses smartphones in order to assist the driver to detect the incoming vehicles from the blind spot area. It seems that more than 60% of mobile phones subscribers in the United States are using smartphones and people are already using smartphones to assist them in their navigation [14].

SideEye contributes an alternative for monitoring function for bringing the blind spot that is approximates the same safety feature of luxury vehicles to economy vehicles. SideEye helps to identify the situation very accurately and it then will warn the driver in real-time. Computer vision related technologies is used in SideEye to scrutinize the scene in the blind spot area.

Although the blind spot areas present on both left and right side of the vehicle, the proposed area to be monitored by SideEye is only on one side which is at the driver side since the risk to cause injury or death once a collision happens on the driver-side is more critical and in more instance there are no other passengers in the vehicle. So, the safety of the driver will be focused more.

The smartphones is mounted on the windshield or on the dashboard which is in front of the driver in order to allow the front camera of the smartphones to monitor the blind spot area. The region of interest (ROI) which is the lane on the side of the driver is the region that the SideEye will monitor covers the blind spot of the driver. The SideEye will alert the driver as soon as possible once it detects vehicle in the ROI to improve safety. The system will also be able to work as a daemon thread with other smartphones applications especially navigation applications. The system will only alert the driver when it detects something critical I the ROI. It will alert the driver in several ways such as showing a warning icon or give an audio warning.

Figure 1.3: A smartphone that is mounted on the windshield [5].

The system uses camera to monitor the ROI and then processes the information in the video frame. Computer vision based techniques is employed by the developer to perform this task. The developer explore two approaches to detect the presence of vehicles in the ROI which is by checking the intensity of the image within the ROI and by the knowledge of the shape of the vehicles.

In the intensity based scheme, the intensity distribution of the pixel of the ROI could be different when there are no vehicles or obstacles on the road. The difference between the intensity of the pixel distribution is utilized to identify the presence of vehicles in the ROI. Another way to distinguish between a vehicle and an empty road is by the intensity variation which means that the intensity variation of the region is observed. The variation of intensity is calculated and a threshold is used in order to distinguish between empty road and occupied road. Normally, most of the pixels concentrated around one peak when the road is empty. The peak may shift once the texture of the road changes but most of the pixels are still concentrated around that region. Once a vehicle enters the region, the pixels will spread and other local peaks will occur. This characteristic is used as a hint to inform the driver about the presence of the vehicle in the blind spot area. The region is warped so that it gives an even distribution of pixels in order to make the system able to detect incoming vehicle as soon as possible.

However, this system has its own advantages. It depends on the camera of the smartphones itself which means the system will become less efficiency if the resolution of the front camera of the smartphone is low. It does help the driver to navigate the blind spot when the smartphone is placed in front of the driver which is on the dashboard or on the windshield. But some drivers may feel uncomfortable with the presence of the smartphone in front of them because the device itself is blocking the drivers view. The system also may not last long as the smartphone itself uses its own battery to power up. More energy will be required and wasted once the driver have to let their smartphones to be in standby mode as the system require the phone to be turn on [5].

2.2.3 Active Blind Spot Crash Avoidance System

An active blind spot crash avoidance system has been develop at Kattering University, Michigan, USA in order to address the concerns of vehicles collisions and accidents that happen during the drivers changing the lane. The system will detect the presence of vehicles in the blind spot of the driver and what lane they are travelling in. The system provides a force on the steering wheel if the driver tend to change lane to where a vehicle is present in the blind spot area so that side collision can be avoided while simultaneously providing an opposite force on the pedal to avoid frontal collision.

Figure 1.4: Illustration of the driving scenario [6].

The situation is explained as follows: Vehicle 'A' is controlled by the driver and need to pass vehicle 'C' either it's right or left. The driver didn't use the side mirrors to look around to look at the blind spot area and this simulates a lane change where the driver will not considering to look at the side mirror. Vehicle 'B' is randomly generated in the drivers blind spot either left or right side. An amber light will be activated on the interior which will alert the driver that there is a vehicle in the blind spot area. Vehicle 'B' will the pass vehicle 'A' and reach the rear bumper but the driver must pass vehicle 'C' otherwise it will hit the rear bumper of vehicle 'C'. Once vehicle 'C' has passed, it will then enter ther blind spot of vehicle 'A'. the driver is then merge to its original lane.

The system is tested by simulation. The simulator is a graphical driving simulator that provides the driver with the sense of driving a car. There are differences between the simulator and driving a real car. The situation is far different. In the simulator, the view of the driver only focused on the screen. Meanwhile, the real situation when driving a car is far different from the simulator as the driver has to consider everything in the surrounding instead of that on the screen in the simulator [6].

Figure 1.5: Driving simulation [6].

2.2.4 Dynamic Side-View Mirror (DAMS)

A system which is called DAMS (Dynamic Angling Mirror System) changes the yaw angle of the side mirror dynamically and therefore it will also change the field of view of the driver. When a vehicle enters the blind spot area of the host vehicle, the yaw angle of the side mirror changes so that the driver will be able to see the approaching vehicle. The yaw angle of the side mirror will turn to its original position once the approaching vehicle passes through and leave the blind spot area. The system senses the adjacent lanes and calculates once the vehicle in the adjacent lane is entering the blind spot by which is by considering the velocity and the distance of the nearest vehicle and then it will change the field of view of the mirror.

Figure 1.6: Change in the yaw angle of the side mirror [15].

However, there are possibility that the driver does not realize the change of the yaw angle of the side mirror or misunderstands the same. This will endanger the driver itself as if the driver didn't see any incoming vehicle through the side mirror when the yaw angle is changed and not at its original angle whereas the driver is looking at the different position [15].

2.2.5 On-Vehicle Imaging System

On-vehicle imaging system is used to capture the status of the inside-view or outside-view by using a camera. They are then integrate signals of the vehicle to alert the driver. The system consists of processing unit, input unit and vehicle signals. The processing unit includes the image processing unit and microprocessor. Digital signal processor is used to the image processing unit. The output unit including display and alert unit.

It uses digital signal processor (DSP) in order to capture image signal from CCD/CMOS image sensor, signals speed, and steering wheel from the microprocessor. To modulate parameter of blind spot area between computer and microprocessor, RS232 interface is integrated. The result of the recognition of the blind spot area is then presented on general monitor. The warning or alert information could be represented by buzzer and LED as an indicator as well.

However, this system which use camera as a sensor to detect the approaching vehicle in the blind spot area may be affected by the light intensity of the surrounding. Thus, the ability to detect vehicles is different at night and day. It may took a long and complicated algorithm to ensure the system detect vehicles at both time [16].

2.2.6 Differences, advantages and disadvantages between the methods.

Table 1: Differences between the methods

	LaRA SideCam	**SideEye**	**Active Blind Spot Crash Avoidance System**	**Dynamic Side-View Mirror (DAMS)**	**On-Vehicle Imaging System**
Sensor used [8, 5, 6, 15, 16]	320 x 240, 30 fps camera.	Smartphones front camera.	Ultrasonic sensor or camera	Camera	Camera with 320 x 240 resolution.
Position of the sensor [8, 5, 6, 15, 16]	Left or right side cars door.	On the dashboard or windshield in front of the driver.	In both sides of door mirrors.	On the side mirror.	On both sides of the door of the vehicle.
Method to detect approaching vehicle [8, 5, 6, 15, 16]	Detect the characteristic elements of the front side of the vehicle and the front wheel.	Utilize the difference of intensity distribution to identify the presence of vehicle.	Measuring the change in the range measured or by algorithm for the camera.	Measuring the change in the range measured or by algorithm for the camera.	Uses digital signal processor (DSP).
Method used by the system to warn the driver [8, 5, 6, 15, 16]	None	Displaying a warning icon or giving an audio warning from the smartphone.	Provide an opposite force on the steering wheel.	Changing the yaw angle of the side mirror.	Providing a signal by LED or buzzer.

Each methods has different engineering approaches in order to warn the driver and the types of the sensor used. All of them uses camera as the sensor for their safety system that has been developed except for Active Blind Spot Crash Avoidance System. The type of the cameras used for each systems are differ to each other. The most portable camera used is in SideEye system where it utilize the camera by the smart phone and this is differ from the other systems that uses cameras which they use normal cameras with different characteristics.

Each sensors for all systems are all mounted on the left or right side of the vehicles except for SideEye which is mounted in front of the driver whether on the dashboard or on the windshield. This is to ensure that the sensor will be able to detect the incoming vehicles in the blind spot area which is mainly on the left and right side of the vehicle.

All the systems have different method or algorithm for the detection of vehicles especially the systems that uses camera. The LaRA SideCam detects the shape of the front vehicles and the front wheel. The SideEye system utilize the difference of intensity distribution to identify the presence of vehicle. Whereas the Active Blind Spot Crash Avoidance System and the Dynamic Side-View Mirror (DAMS) system measures the change in the range measured by the algorithm viewed by the camera. While On-Vehicle Imaging System uses digital signal processor in its system.

There are no method to warn the driver in the system in LaRA SideCam. It just detect the presence of vehicle by its algorithm. A warning icon will be displayed or an audio warning will be given by the smartphone in SideEye system. Active Blind Spot Crash Avoidance System will provide an opposite force on the steering wheel to resist the driver's attempt to change to other lane. Dynamic Side-View Mirror (DAMS) will be able to change the yaw angle of the side mirrors once any vehicle in the blind spot is detected. While On-Vehicle Imaging System will provide a signal by LED or buzzer.

Table 2: Advantages and disadvantages of the methods

Methods	**Advantages**	**Disadvantages**
LaRA SideCam	The high resolution of the camera will be able to detect the image of the front side of the vehicles.	The system may be affected by noise and the change in the intensity of the light. The size of the camera itself will block the view of the driver.
SideEye	Intensity Variation and Intensity Variation with Warping able to detect the situation in the ROI correctly with accuracy about 87%.	Requires good resolution of front camera of smartphones and may be affected by the intensity of the light and the position of the smartphone.
Active Blind Spot Crash Avoidance System	The opposite force from the system will be able to warn the driver and automatically avoid collision at the same time.	The system is only applied to a simulation and not suitable for the real driving situation.
Dynamic Side-View Mirror	The driver able to see the approaching vehicle in the blind spot area just by looking at the side mirror.	The driver might get confused by the change of the yaw angle of the side mirror and misunderstood the current situation.
On-Vehicle Imaging System	The camera used will be able to detect the approaching vehicle accurately.	The system may be affected by the intensity of the surrounding light.

Although the camera in LaRA SideCam has a high resolution and has the ability to detect the incoming vehicle, it may be affected or disturbed by the presence of noise from the surrounding and the intensity of the light. So as the ON-Vehicle Imaging System. The sensor which is camera also requires space to be mounted on the side of the vehicle and the camera itself will block the vision of the driver. The SideEye system requires good resolution of the front camera of smartphones to ensure the system works perfectly and the smartphone itself will block the view of the driver. The driver of a vehicle that uses Dynamic Side-View Mirror may get confused once the side mirror change its yaw angle.

2.3 Summary

Each methods has their own advantages and disadvantages. Since most of them use camera, the disadvantages are mostly related to the efficiency of the camera used. It requires very complex algorithm to ensure it works better. It may be affected to the intensity of the surrounding light since it is different between night and day.

After considering all the pros and cons in all the available methods, the methods that is to be chosen in this project is by using an Arduino as the microcontroller and ultrasonic sensor as the sensor to detect the approaching vehicle in the blind spot area. The Arduino is chosen is due to its own advantages so as the ultrasonic sensor. The system will also be simpler compared to the other available methods.

2.4.1 Arduino

The microcontroller that is chosen to be used for the system is Arduino since it has more advantages. Arduino is a tiny computer that can be programmed to process input and output signal that moving into or out from the chip. Arduino is known as a Physical or embedded Computing platform that through the use of hardware and software. Arduino can be easily programmed, compile and uploaded. It requires no other devices to ensure it operates other than the power supply. Its small size make it portable and can be easily installed to any hardware or system.

Figure 1.7: Arduino UNO which is also one of the types of Arduino.

Figure taken from: https://www.sparkfun.com/products/11021

It can be used in order to develop a stand-alone interactive objects or can be connected to a computer to receive or transmit data to the Arduino and then act on the data. Arduino can be connected to LED's motors, buttons, switches, distance sensors, webcams, printers, GPS receivers or Ethernet module. The Arduino board is made of an Atmel AVR Microprocessor, crystal or oscillator and a 5V linear regulator.

The Arduino can also be extended with the use of 'Shields'. The 'Shields'are circuit boards that hold othe devices such as GPS receivers and LCD displays. The most common type of Arduino available is the Diecimila or the Duemilanove. The chip of the Arduino must be pre-programmed with the Arduino Bootloader to make sure it is able to work with the Arduino IDE [17].

2.4.2 Ultrasonic sensor

An ultrasonic sensor is used to detect the vehicles. Camera is not chosen because of its complexity of the algorithm and requires more time and cost to be done. Moreover, camera may be affected to the surroundings especially the intensity of light and the shape of the detected obstacles or objects. Thus, it may cause errors and cause flaw to the system. Camera itself requires more space to be mounted on certain area. Small cameras would save more spaces but its resolution may become lower and this will affect the system as the higher the resolution of the camera, the better the performance of the system. Therefore, a good blind spot detection system requires a good resolution and at the same time the size of the camera will be larger.

Ultrasonic waves are sounds that can't be heard by human ears and have the frequencies above 20 kHz. Ultrasonic waves are reflected on objects in order to detect the presence of objects. Several materials such as metal, wood, glass and paper reflect approximately 100% of the waves and will cause the object able to be detected. Soft materials such as cloth, cotton and wool are difficult to be detected as these materials absorb the ultrasonic waves.

Ultrasonic sensor is suitable to be applied into the system to detect vehicles as all external part of the vehicles which are the body part able to reflect the ultrasonic waves. The body of the vehicles which are mostly consists of aluminum, rubber, plastic and fiberglass will reflect almost 100% of the propagated ultrasonic waves [18].

CHAPTER 3

METHODOLOGY

3.1 Introduction

Project methodology describes the methods or procedures that has to be done for the development of the project. In this chapter, the theoretical analysis of the method that has been applied to this project will be described. This part consists of process flow chart, development process and experiment that has been conducted.

3.2 Project activity and planning

Based on the flow chart as shown in Figure 1.8, the project is started with the study of the concept review of the system that has been proposed and used in order to detect incoming vehicle in the blind spot area. Then it is followed by identifying the problems which is based on the development of the project. The problem statement also comprises of the performance of the system. Literature review has been drafted and presented based on the researches that has been done before and related to this project. The literature review act as references which help to understand the progress of the project, problems, and resources for analysis. The development process for the system is carried out after the literature review part is done which includes the process for the circuit design, selection of the components and simulation of the circuit and prototyped. After that, the system is tested and troubleshooting the function and performance is carried out.

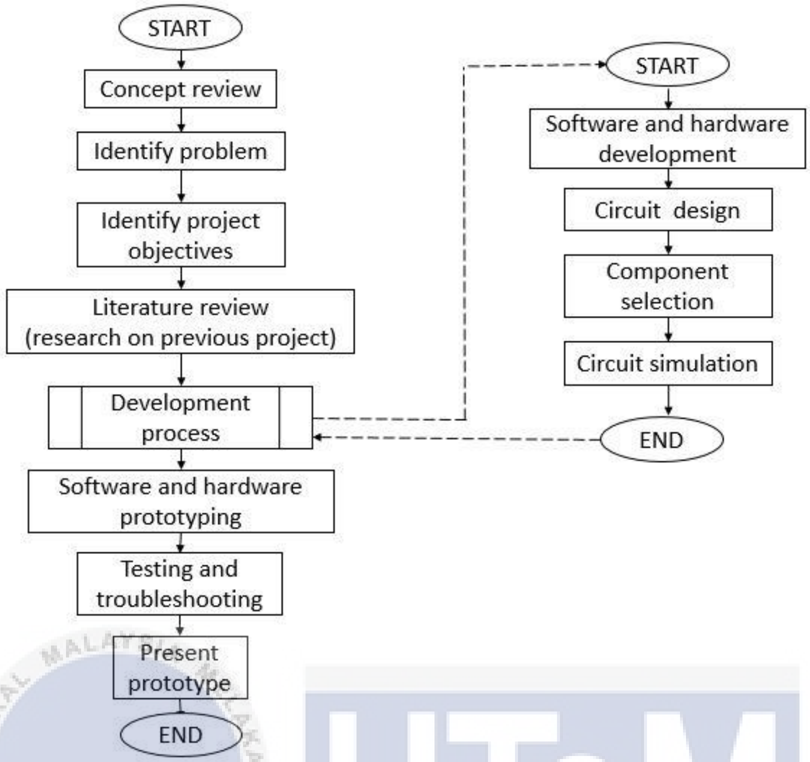

Figure 1.8: Flow chart of the progress for the whole project

For the troubleshooting phase, the error which is mainly from the data that has been obtained before that is the distance measured over time and the distance that will activate the indicator which is the LED.

3.2.1 Milestone

Table 3 shows the planned milestone of activity. The activities that has been planned may change depends on the situation and advice from the supervisor.

Table 3: Planning activity

No.	Activity	Date
1	Implementation of the project • Theoretical study • System design	7th November 2014
2	Hardware implementation	27th January 2015
3	System implementation	22nd February 2015
4	Preparation for the required sample for test guideline	23rd February 2015
5	Running an experiment and collect all data required.	8th March 2015
6	Hardware test and troubleshooting	7th April 2015
7	Analysis of hardware performance	16th May 2015

3.3 Development process

This section will explain the overall process of the vehicles blind spot detection and warning system.

3.3.1 Process flow chart

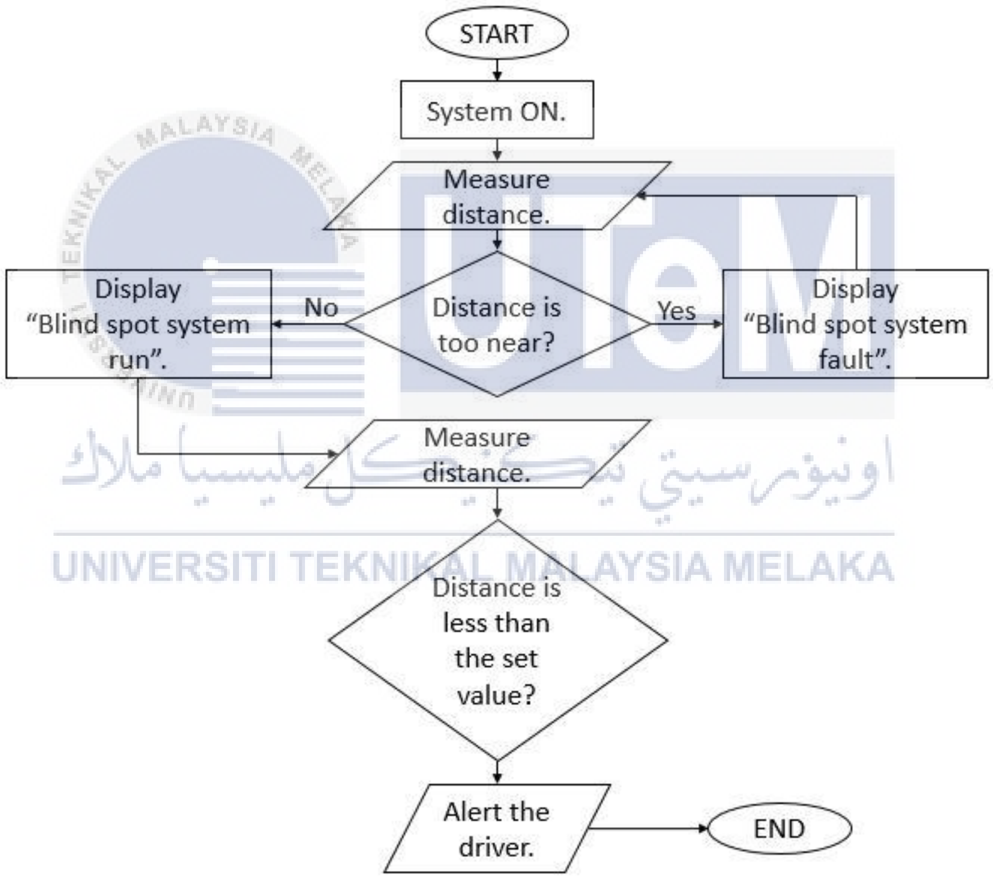

Figure 1.9: Process flow chart

Figure 1.9 shows the process flow chart of the operation of the vehicle blind spot detection and warning system. Once the system is on, the SRF04 ultrasonic sensor will start measuring the distance. If the distance is too near which the measured value is around 2cm, "Blind spot system fault" will be displayed at the 16x2 display. Otherwise, it will continue measuring the distance and "Blind spot system running" will be displayed. If the measured distance is lower than the set value is less than the set value, the system will alert the driver.

3.3.2 Electrical system

The electrical circuit is designed for the system by using Fritzing software. The software helps to design electrical circuit with the actual components that is used in this project. However, some components like the SRF04 ultrasonic sensor could not be found in the software. The components used are as follows:

1. Arduino microcontroller.
2. Ultrasonic sensor (SRF04)

Arduino microcontroller is used to measure the input signal from the ultrasonic sensor (SRF04) that is connected to digital pins of the microcontroller.

Figure 2.0: SRF04 ultrasonic sensor

Figure taken from: http://www.robot-electronics.co.uk/htm/srf04tech.htm

An ultrasonic sensor is used to detect the vehicles. The type of ultrasonic sensor used is SRF04. The specifications of the sensor is as follows:

1. The maximum range that can be detected is about 10.7m.
2. The current consumption is 2.5A.
3. The quiescent current is 150mA.
4. The minimum measured range is 2cm.

SRF04 ultrasonic is designed to be used as the Polaroid sonar which requires a short trigger pulse and providing an echo pulse. The pin connections are shown as in Figure 2.1:

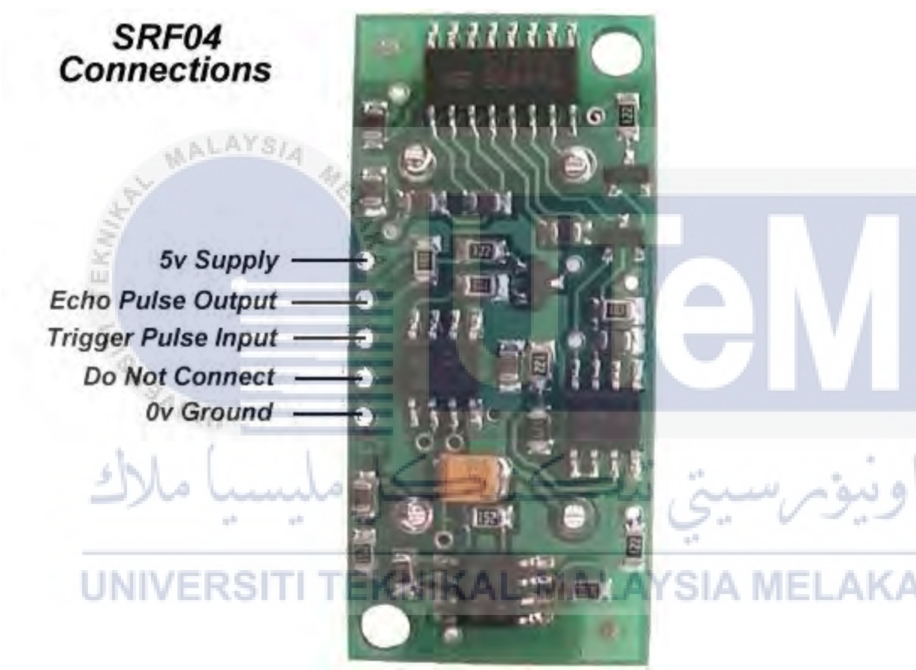

Figure 2.1: Pin connections of SRF04

Figure taken from: http://www.robot-electronics.co.uk/htm/srf04tech.htm

Only a short 10µs supply is needed to trigger the input to start the ranging or distance measurement. It will send out an 8 cycle ultrasound burst at 40 kHz frequency and raise its echo line high. Then, it listens for an echo. As soon as it detects one, it lowers the echo one more time. The echo line is a pulse which its width is proportional to the distance to the object. It is possible to calculate the range in inches or centimeters from timing the pulse. If there were nothing is detected, then the SRF04 ultrasonic sensor will lower its echo line after about 36ms. The timing diagram for the SRF04 is shown as in Figure 2.2:

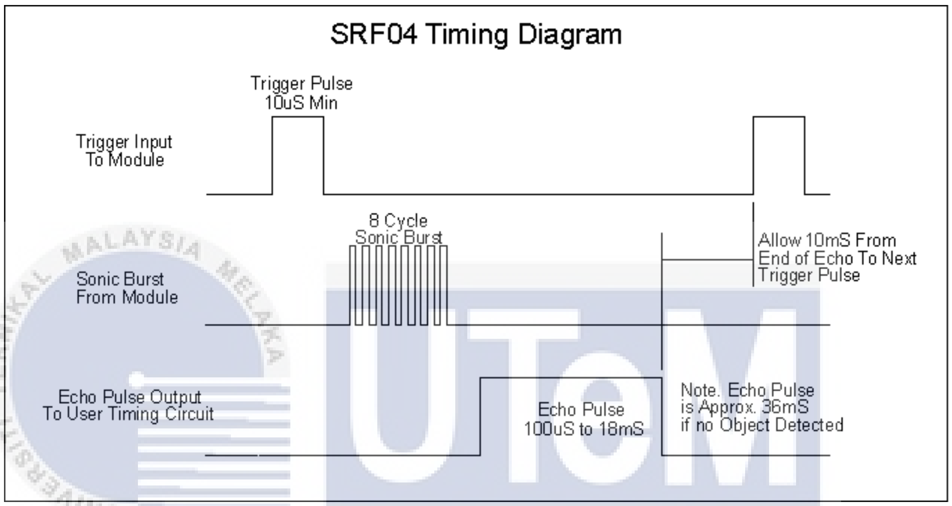

Figure 2.2: Timing diagram for SRF04 ultrasonic sensor.

Figure taken from: http://www.robot-electronics.co.uk/htm/srf04tech.htm

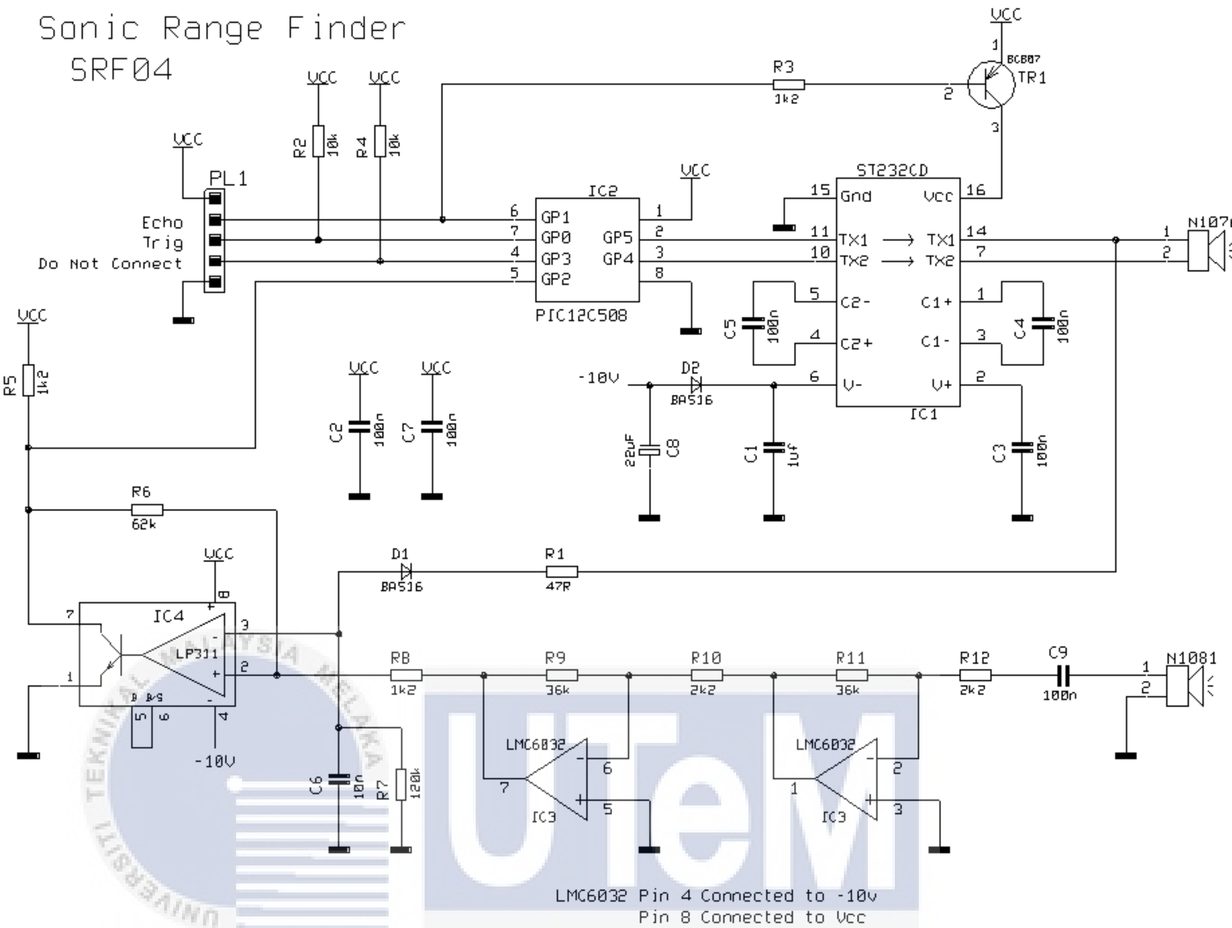

Figure 2.3: Schematic diagram for SRF04

Figure taken from: http://www.robot-electronics.co.uk/htm/srf04tech.htm

It uses a PIC12C508 to control the functions and standard 40 kHz piezo transducers. The transmitting transducers drive could be driven directly from the PIC. The 5V supply able to give an enough power to the whole sensor to measure distance. The sensor could stand 20V of drive. The receiver is a two stage operational amplifier circuit.

The SRF04 ultrasonic sensor provides an echo pulse which is proportional to the distance. To obtain the reading in centimeters (cm), the width of the pulse is measured in μs and then is divided by 58. If it is divided by 148, a distance in inches will be given [18]. The angle covered is 55º.

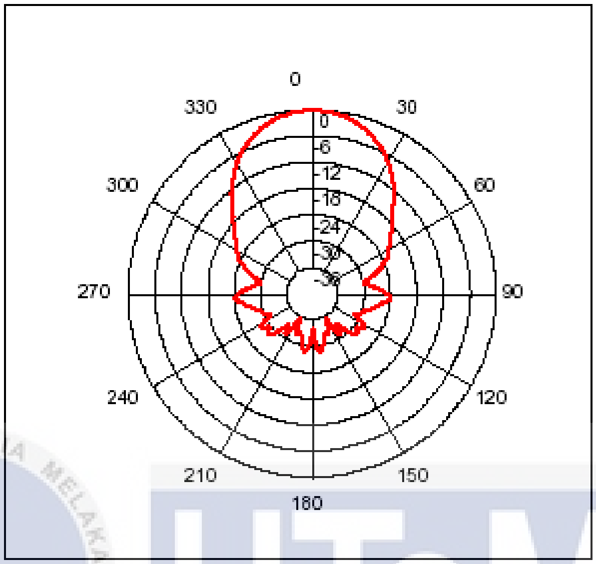

Figure 2.4: The beam pattern of the SRF04

Figure taken from: http://www.robot-electronics.co.uk/htm/srf04tech.htm

3.4 Experiment setup

3.4.1 Sensor performance

3.4.1.1 Experiment 1:

Objective:

To analyze the range measured by the sensor by using different materials.

Apparatus:

i. Three different materials which are plastic, aluminum, and fiberglass. These three types of materials are chosen because most vehicles body parts are made from aluminum, plastic or fiberglass.
ii. Measuring tape.
iii. Ultrasonic sensor (SRF04)

Procedure:

1. The trigger and echo pins of the ultrasonic sensor is connected to the digital pins of the Arduino microcontroller.
2. The Arduino microcontroller is then programmed ad compiled. The program is as follows:

```
#define ECHOPIN 30                          // Pin to receive the echo pulse
#define TRIGPIN 31                          // Pin to send the trigger pulse

void setup()
{
  Serial.begin(9600);
  pinMode(ECHOPIN, INPUT);
  pinMode(TRIGPIN, OUTPUT);
}
void loop()
{
  digitalWrite(TRIGPIN, LOW);               // Set the trigger pin to low for 2µS
  delayMicroseconds(2);
  digitalWrite(TRIGPIN, HIGH);              // Send a 10µS high to trigger ranging
  delayMicroseconds(10);
  digitalWrite(TRIGPIN, LOW);               // Set pin low again
  int distance = pulseIn(ECHOPIN, HIGH);    // Number of times pulse read
  distance= distance/58;                    // Calculate distance
  Serial.println(distance);
  delay(50);                                // Delay 50mS before next ranging
}
```

3. The program is the uploaded to the Arduino microcontroller.

4. The object which is placed 100cm in front of the SRF04 ultrasonic sensor after is measured by using a measuring tape.

5. The speed of the moving object is estimated with the help of Android application.

Figure 2.5: Android application for speed capture

6. The object which is plastic based object is pushed towards the SRF04 ultrasonic sensor at speed about 10km/h.
7. The same object is then pushed towards the SRF04 ultrasonic sensor about 30km/h.
8. The data for both speeds 10km/h and 30km/h which are obtained from the serial monitor of the Arduino are then obtained and recorded.
9. Steps five until seven are then repeated by replacing the object with fiberglass and aluminum.

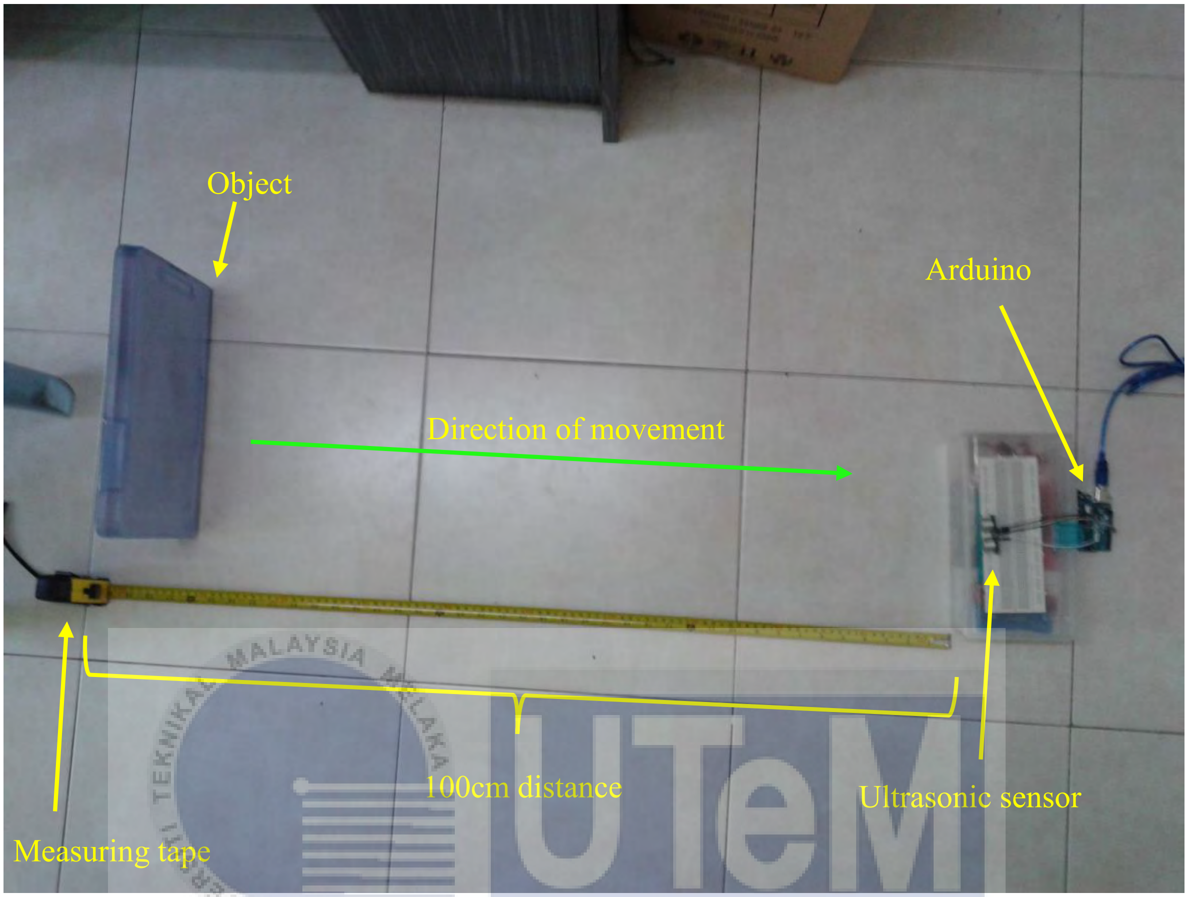

Figure 2.6: The set up for the experiment

4.2 Experiment 2:

Objective:

To analyze the response of the system towards the incoming vehicle in the blind spot area with two different position of the sensor with the sensor at static position.

Equipment:

i. SRF04 ultrasonic sensor.
ii. Measuring tape.
iii. A motorcycle (1.889m length and 0.706m width).
iv. A car.

Procedure:

1. The blind spot area which is opposing the rear tire is measured from the rear tire.
2. The distance for the alarm to turn on when the incoming vehicle is detected is set to the distance measured before which is 150cm.

3. The program is uploaded into the Arduino Uno which the program is as follows:

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
#define ECHOPIN 8
#define TRIGPIN 9
int led1=13;
int led2=10;

void setup()
{
  Serial.begin(9600);
  pinMode(ECHOPIN, INPUT);
  pinMode(TRIGPIN, OUTPUT);
  pinMode(led1, OUTPUT);
  pinMode(led2, OUTPUT);

  lcd.begin(16, 2);
  lcd.print("Blind spot ");
  lcd.setCursor(0, 1);
  lcd.print("system running");
}

void loop(){
  digitalWrite(TRIGPIN, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIGPIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIGPIN, LOW );
  int distance = pulseIn(ECHOPIN, HIGH);
  distance= distance/58;
  Serial.println(distance);
```

```
delay(20);

if(0<distance&&distance<150)
{
  digitalWrite(led1, HIGH);
  digitalWrite(led2, HIGH);
}

else if(distance<4)
{
  digitalWrite(led1, HIGH);
  digitalWrite(led2, HIGH);

  lcd.begin(16, 2);
  lcd.print("Blind spot ");
  lcd.setCursor(0, 1);
  lcd.print("system failure");
  delay(50);

  lcd.begin(16, 2);
  lcd.print("Blind spot ");
  lcd.setCursor(0, 1);
  lcd.print("system running");

}
  else
{
  digitalWrite(led1, LOW);
  digitalWrite(led2, LOW);
    }
}
```

4. The SRF04 ultrasonic sensor is mounted 15cm above the rear tire of a car which is 73.1cm above the ground as shown in the Figure 2.7.

Figure 2.7: Sensor above the rear tire

5. While the sensor is in static position, which is the velocity of the car is $0ms^{-1}$, a motorcycle is let to move passing by the car which is also in front of the SRF04 ultrasonic sensor at a constant velocity of 20kmph ($5.5556ms^{-1}$) as shown in Figure 2.8.

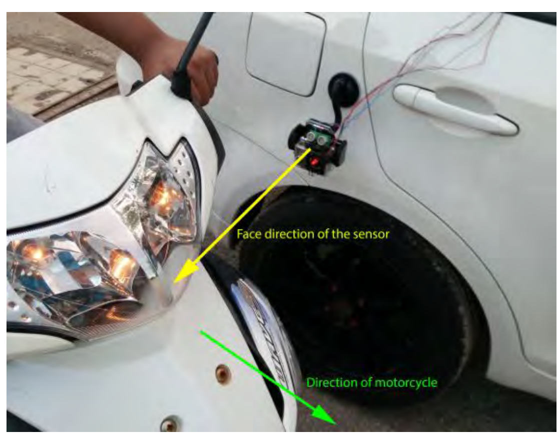

Figure 2.8: Face direction of the sensor and the direction of motorcycle.

6. The data is collected from the serial monitor of the Arduino software which the sampling time is 20ms. The sampling time is set to 20ms because it is the lowest sampling time that the sensor able to detect. Lower than 20ms will give unstable measurement of the sensor and yet the system will not able to turn on the alarm correctly. If it set more than 20ms will result the larger sampling of the data and the respond of the system will be slower.
7. Steps 5 and 6 are repeated with the velocity of the passing by motorcycle is 40kmph (11.1111ms^{-1}) and 60kmph (16.6.6667ms^{-1}).
8. Steps 1 to 8 is repeated with the sensor is mounted under the side mirror with the angle of 45º slant as shown in Figure 2.9.

Figure 2.9: 45º slant of the sensor

3.4.1.3 Experiment 3:

Objective:

To analyze the respond of the system towards the incoming vehicle in the blind spot area with two different position of the sensor with the sensor is moving constant velocity.

Apparatus:

i. SRF04 ultrasonic sensor.
ii. Measuring tape.
iii. A motorcycle (1.889m length and 0.706m width).
iv. A car.

1. The blind spot area which is opposing the rear tire is measured from the rear tire.
2. The distance for the alarm to turn on when the incoming vehicle is detected is set to the distance measured before which is 150cm.
3. The SRF04 ultrasonic sensor is mounted 15cm above the rear tire of a car which is 71cm above the ground as shown in the Figure 3.0 and Figure 3.1.

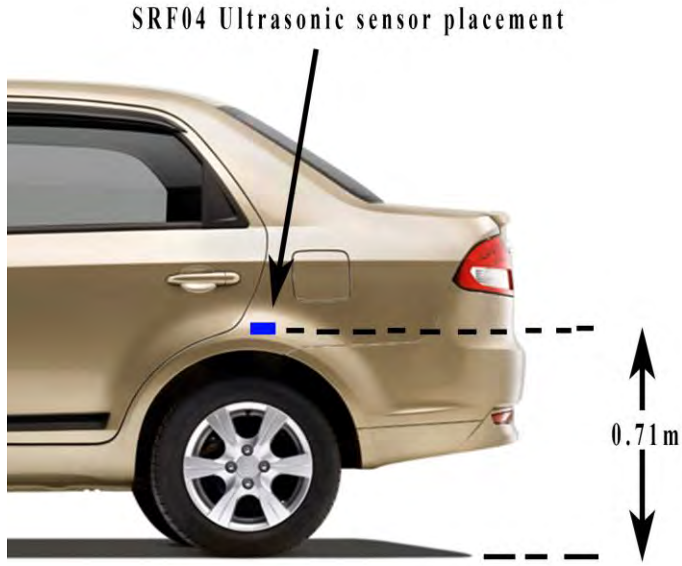

Figure 3.0: Side view of sensor placement for above rear tire.

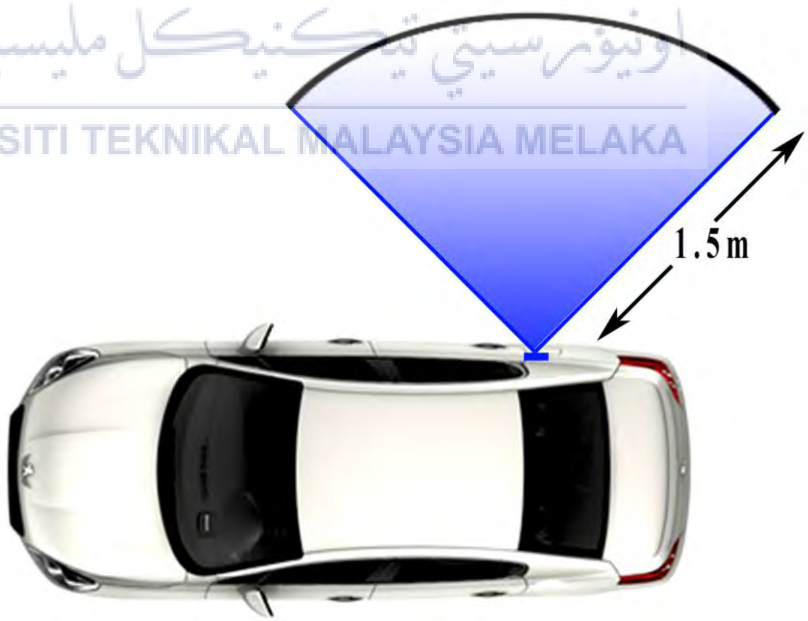

Figure 3.1: Top view of sensor placement for above the rear tire and the range covered.

4. While the sensor is moving at a constant velocity of 20kmph ($5.5556ms^{-1}$), a motorcycle is let to move passing by the car which is also in front of the SRF04 ultrasonic sensor at a constant velocity of 40kmph ($11.1111ms^{-1}$) as shown in Figure 3.2.

Figure 3.2: Motorcycle passing by the car with the sensor.

5. The data is collected from the serial monitor of the Arduino software which the sampling time is 20ms.
6. The test is repeated with the speed of the sensor is 40kmph (11.1111ms^{-1}) and the speed of the motorcycle is 60kmph (16.6667ms^{-1}).
7. The whole experiment is repeated for the SRF04 ultrasonic sensor is mounted under the side mirror with an angle 45° slant.

CHAPTER 4

RESULTS

The results for this project will be presented in this chapter. The results is obtained from the experiments that has been conducted and tabulated in table form and graph. Based on the results, the performance of the ultrasonic sensor is analyzed and discussed.

4.1 Experiment 1:

The purpose of this experiment is to make an analysis on the range measured by the sensor by using different materials that is moving towards the sensor at 2 different speed which is at 10km/h and 30km/h. The data are as follows:

Material: Plastic

Closing speed: 10km/h

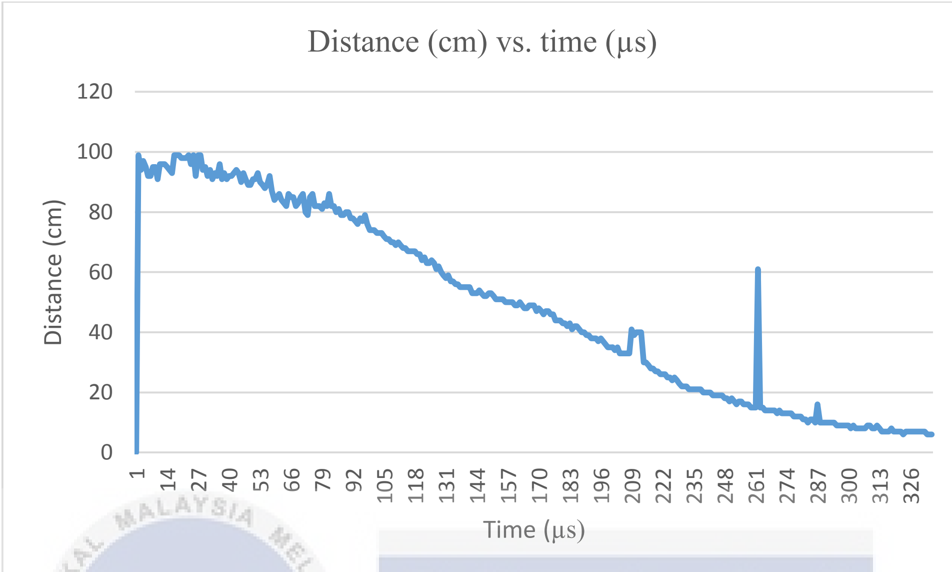

Figure 3.3: Graph of measured distance over time for plastic material moving at 10km/h

Figure 3.3 shows the graph represents the data taken which is the distance measured in cm against time in µs. The object which is plastic based object is placed 100cm in front of the SRF04 ultrasonic sensor and pushed towards the sensor at 10km/h. The distance measured is decreasing with time. The initial measurement is fluctuating about the actual distance which the deviation is about 10cm. The deviation is then decreased to about 2cm from the desired value which the difference is about 40cm. There are a few times which the deviation as is far from the desired value. The source of the error is due to the surrounding environment and the inconsistency of the speed of the object.

Material: Plastic

Closing speed: 30km/h

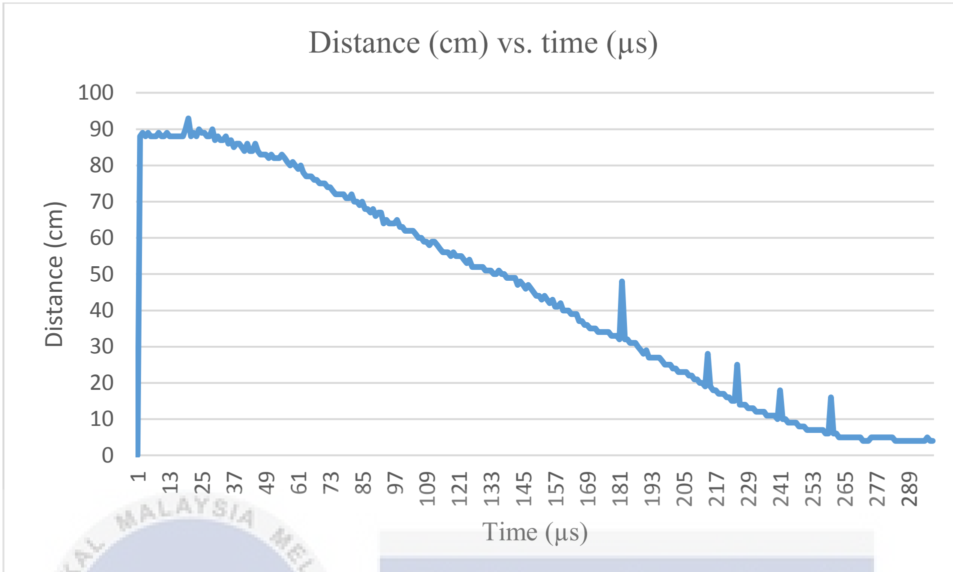

Figure 3.4: Graph of measured distance over time for plastic material moving at 30km/h

Figure 3.4 shows the graph represents the data taken which is the distance measured in cm against time in µs. The object which is plastic based object is placed 100cm in front of the SRF04 ultrasonic sensor and pushed towards the sensor at 30km/h. The distance measured is decreasing with time. The measurement is fluctuating about the actual distance which the deviation is about 1cm to 2cm. The deviation is consistence until the end of the measurement. However, there are also peaks where the distance measured is about 10cm from the actual reading. The source of the error is due to the surrounding environment and the inconsistency of the speed of the object.

Material: Fiberglass

Closing speed: 10km/h

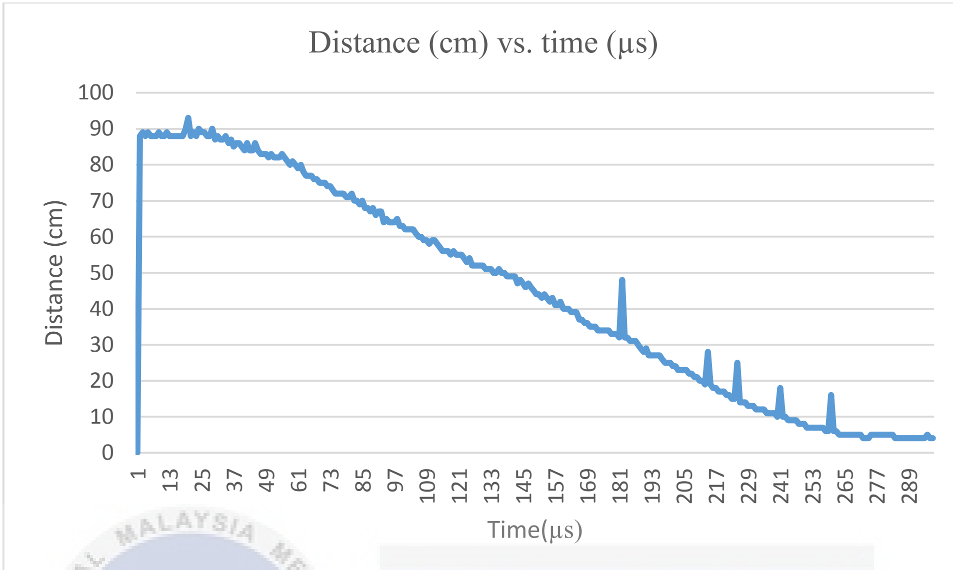

Figure 3.5: Graph of measured distance over time for fiberglass material moving at 10km/h

Figure 3.5 shows the graph represents the data taken which is the distance measured in cm against time in µs. The object which is fiberglass based object is placed 100cm in front of the SRF04 ultrasonic sensor and pushed towards the sensor at 10km/h. The distance measured is decreasing with time. The measurement is fluctuating about the actual distance which the deviation is about 1cm to 2cm. The deviation is decreases as the object is nearer to the sensor. The source of the error is due to the surrounding environment and the inconsistency of the speed of the object.

Material: Fiberglass

Closing speed: 30km/h

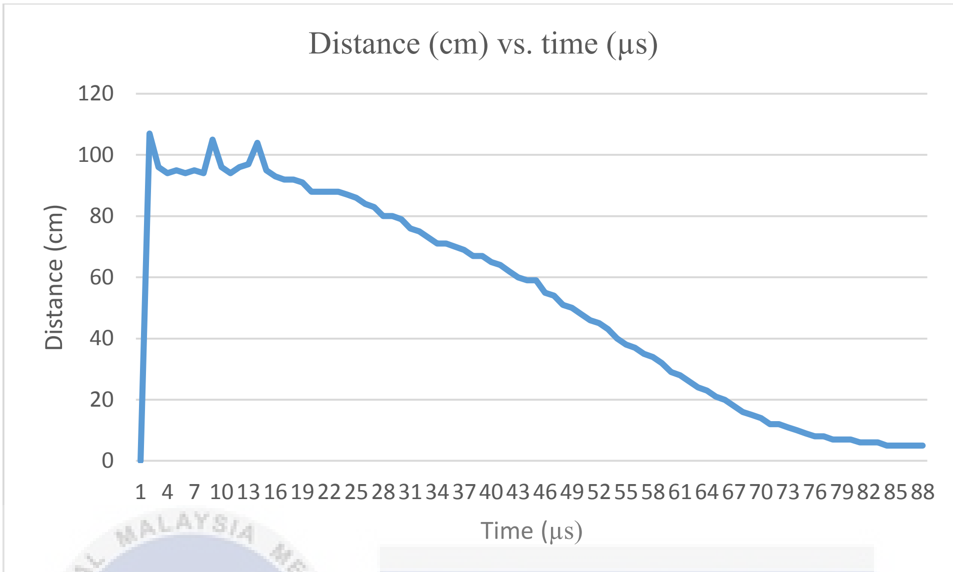

Figure 3.6: Graph of measured distance over time for fiberglass material moving at 30km/h

Figure 3.6 shows the graph represents the data taken which is the distance measured in cm against time in µs. The object which is fiberglass based object is placed 100cm in front of the SRF04 ultrasonic sensor and pushed towards the sensor at 30km/h. The distance measured is decreasing with time. The measurement is fluctuating about the actual distance which the deviation is about 10cm. The deviation is decreases as the object is nearer to the sensor. The source of the error is due to the surrounding environment and the inconsistency of the speed of the object.

Material: Aluminum

Closing speed: 10km/h

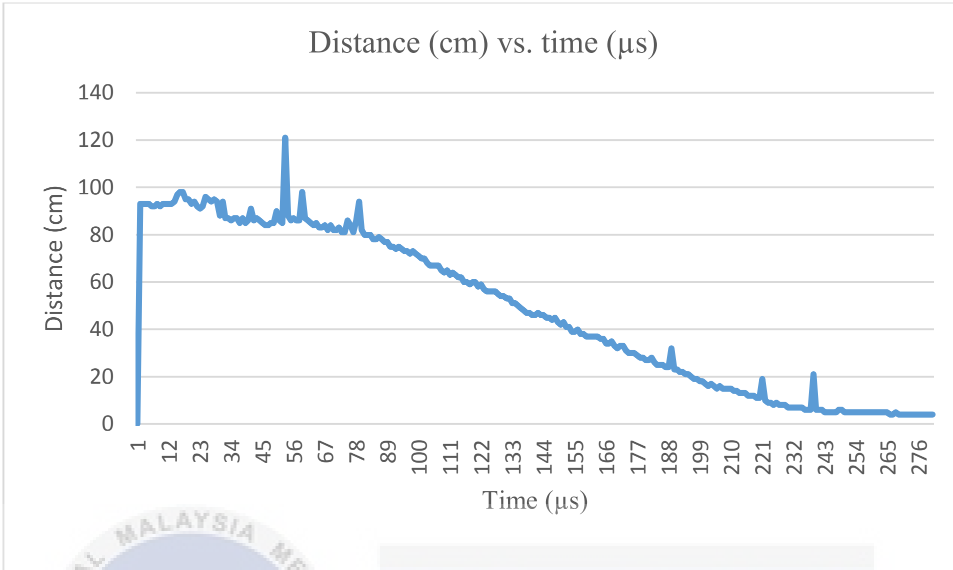

Figure 3.7: Graph of measured distance over time for aluminum material moving at 10km/h

Figure 3.7 shows the graph represents the data taken which is the distance measured in cm against time in µs. The object which is fiberglass based object is placed 100cm in front of the SRF04 ultrasonic sensor and pushed towards the sensor at 10km/h. The distance measured is decreasing with time. The measurement is fluctuating about the actual distance which the deviation is about 10cm. The deviation is decreases as the object is nearer to the sensor. However, there are a few times which the measurement is too far from the desired reading. The source of the error is due to the surrounding environment and the inconsistency of the speed of the object.

Material: Aluminum

Closing speed: 30km/h

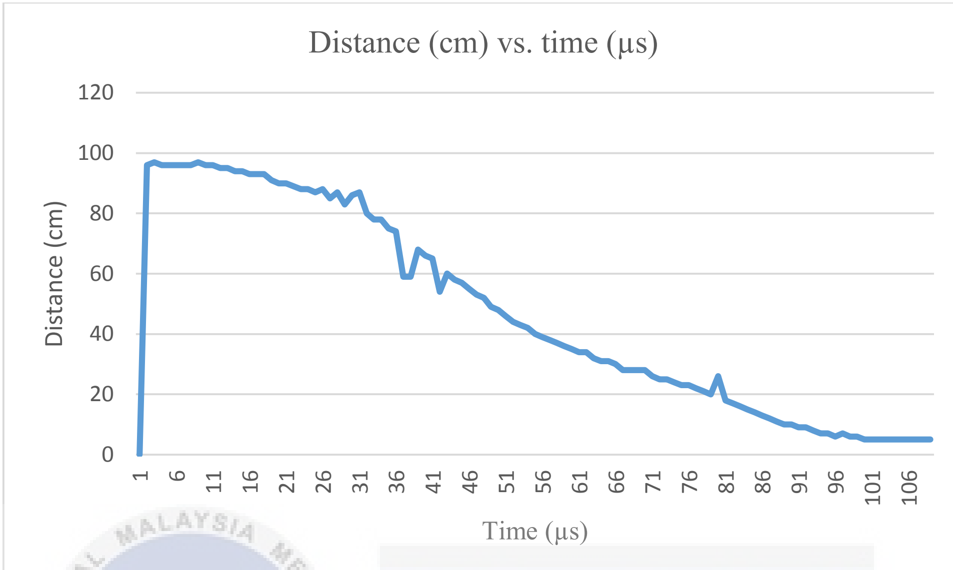

Figure 3.8: Graph of measured distance over time for aluminum material moving at 30km/h

Figure 3.8 shows the graph represents the data taken which is the distance measured in cm against time in µs. The object which is aluminum based object is placed 100cm in front of the SRF04 ultrasonic sensor and pushed towards the sensor at 30km/h. The distance measured is decreasing with time. The measurement is fluctuating about the actual distance which the deviation is about 5cm. The deviation is decreases as the object is nearer to the sensor. However, there are a few times which the measurement is too far from the desired reading .The source of the error is due to the surrounding environment and the inconsistency of the speed of the object.

3.4.1.2 Experiment 2:

The purpose of this experiment is to make an analysis on the time response of the system with two different position of the sensor which is above the rear tire and under the side mirror with 45º slant. The data are as follows:

Sensor position: Above rear tire

Speed of motorcycle passing by the sensor: 20kmph ($5.5556ms^{-1}$).

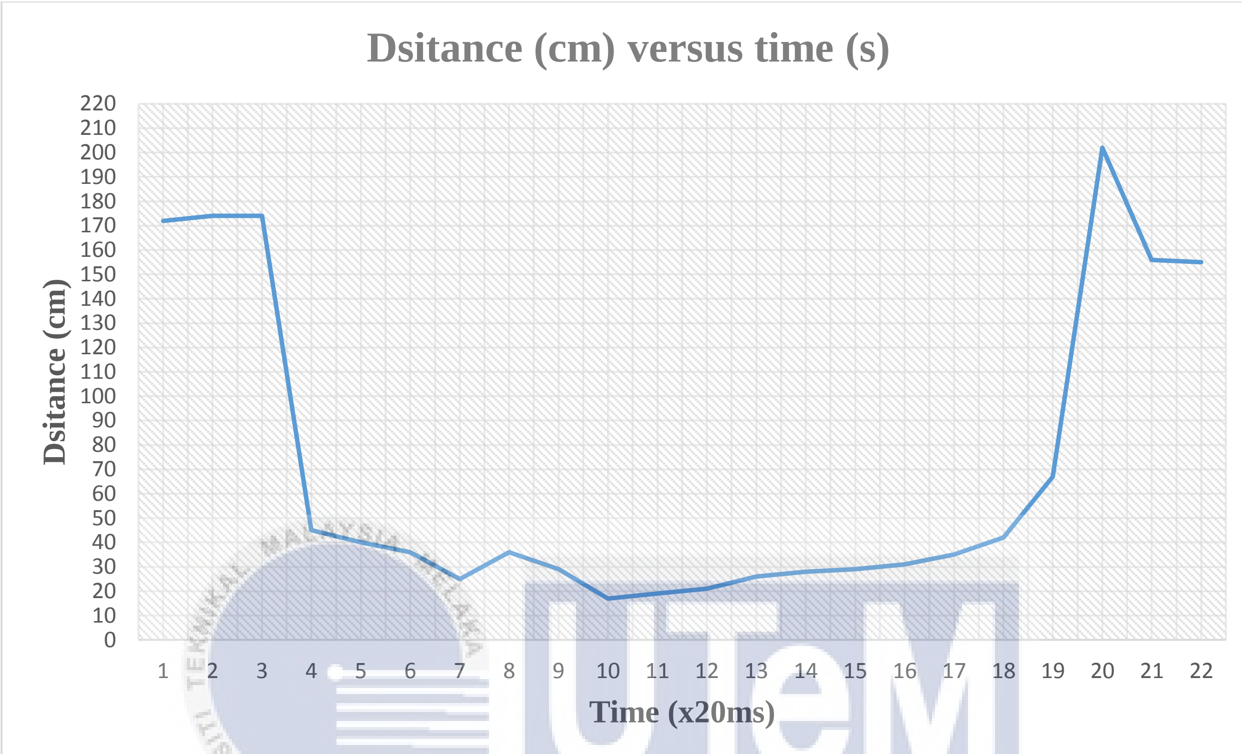

Figure 3.9: Graph of measured distance over time for motorcyle moving at 20kmph ($5.5556ms^{-1}$)

Figure 3.9 shows the data taken for the sensor which is positioned above rear tire and it is pointing outwards. The distance that has been set so that the alarm will turn on is 150cm so that the alarm will warn the driver if the distance is less than that length. Based on the Figure , at 20kmph ($5.5556ms^{-1}$), the motorcycle is in the SRF04 ultrasonic region at that position is from t=3 to t=20. The distance measured by the sensor starts decreasing at t=3.Since the sampling time is every 20ms therefore,

$$(20 - 3) \times 20ms = 0.34\ seconds$$

The motorcycle is in the region of the sensor for 0.34 seconds.

Since the distance set for the alarm will turn on if the distance is less than 150cm, alarm is turned on in the region between t=3.6 and t=19.2. Since the sampling time is every 20ms,

$$(19.2 - 3.6) \times (20ms) = 0.312\ seconds$$

Thus, the alarm is on for 0.312 seconds.

Therefore, the difference between the time of that motorcycle in the region of the SRF04 ultrasonic sensor and the region which is set 150cm is:

$$0.34\ seconds - 0.312\ seconds = 0.028\ seconds$$

Sensor position: Above rear tire

Speed of motorcycle passing by the sensor: 40kmph ($11.1111ms^{-1}$).

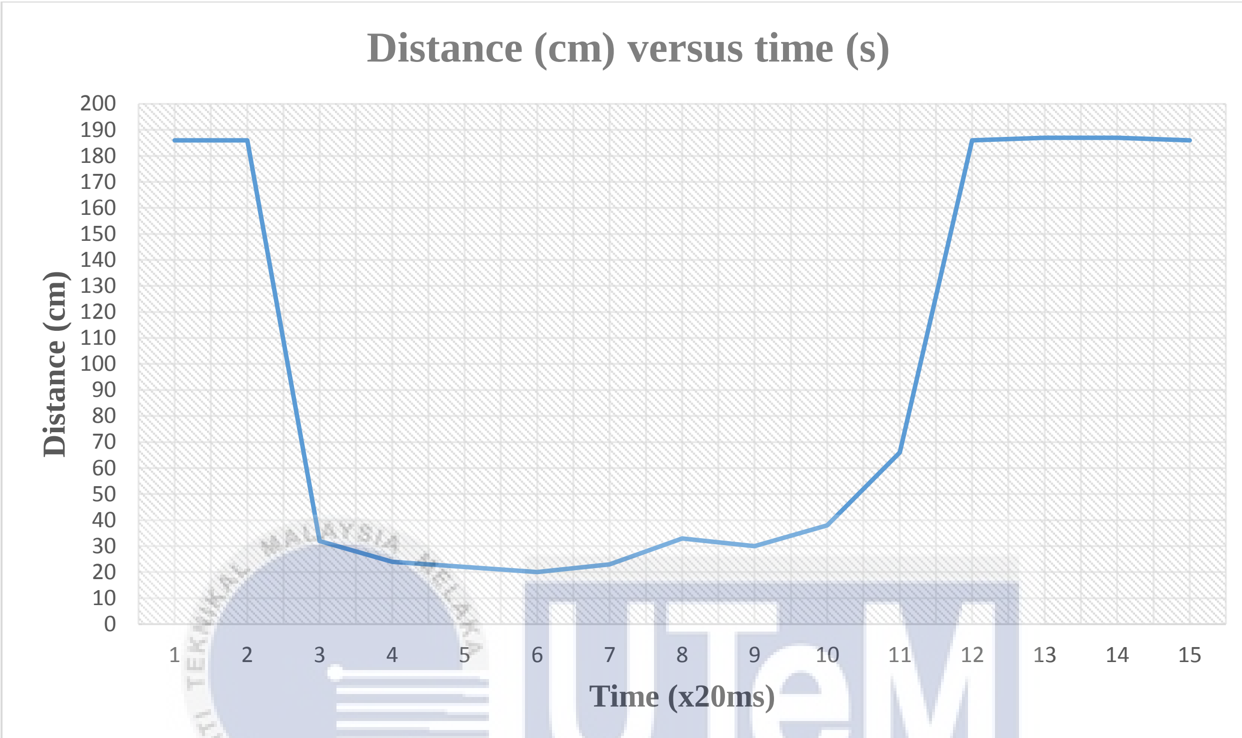

Figure 4.0: Graph of measured distance over time for motorcyle moving at 40kmph ($11.1111ms^{-1}$)

Figure 4.0 shows the data taken for the sensor which is positioned above rear tire and it is pointing outwards. The distance that has been set so that the alarm will turn on is 150cm so that the alarm will warn the driver if the distance is less than that length. Based on the Figure , at 40kmph ($11.1111ms^{-1}$), the motorcycle is in the SRF04 ultrasonic region at that position is from t=2 to t=12. The distance measured by the sensor starts decreasing at t=2.Since the sampling time is every 20ms therefore,

$$(12-2) \times 20ms = 0.2\ seconds$$

The motorcycle is in the region of the sensor for 0.2 seconds.

Since the distance set for the alarm will turn on if the distance is less than 150cm, alarm is turned on in the region between t=2.3 and t=11.7. Since the sampling time is every 20ms,

$$(11.7 - 2.3) \times \ (20ms) = 0.188 \ seconds$$

Thus, the alarm is on for 0.188 seconds.

Therefore, the difference between the time of that motorcycle in the region of the SRF04 ultrasonic sensor and the region which is set 150cm is:

$$0.2 \ seconds - 0.188 \ seconds = 0.012 \ seconds$$

Sensor position: Above rear tire

Speed of motorcycle passing by the sensor: 60kmph (16.6667ms^{-1}).

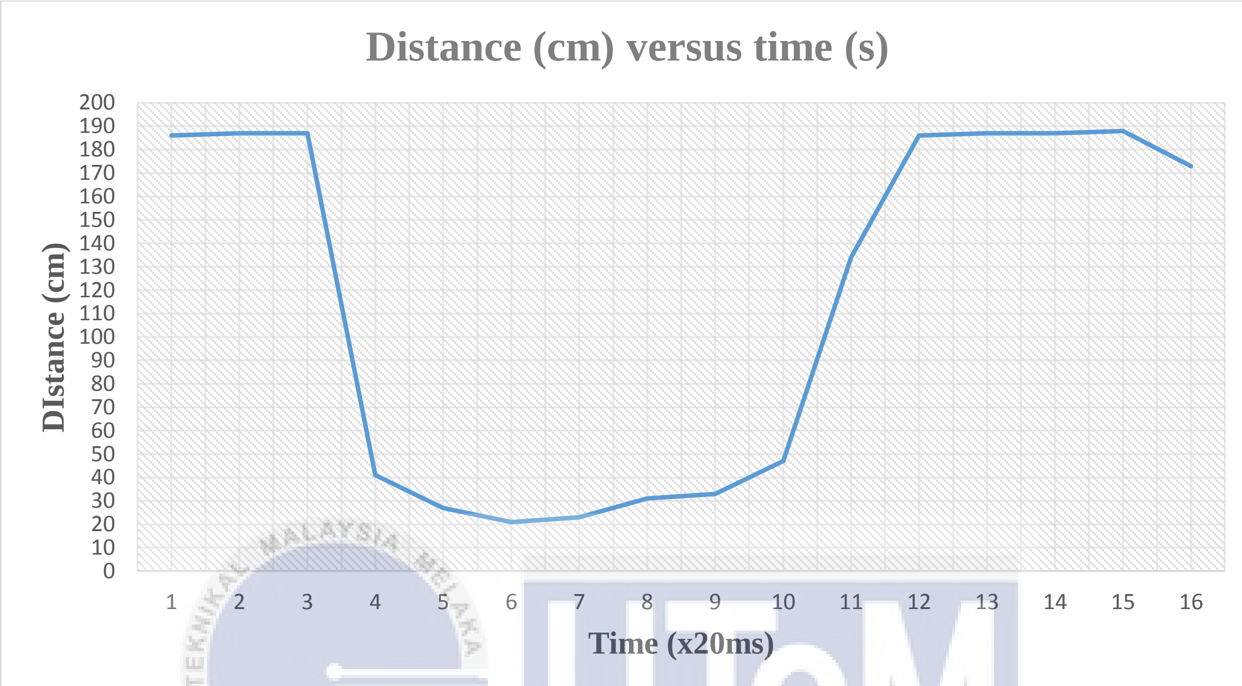

Figure 4.1: Graph of measured distance over time for motorcyle moving at 60kmph (16.6667ms^{-1})

Figure 4.1 shows the data taken for the sensor which is positioned above rear tire and it is pointing outwards. The distance that has been set so that the alarm will turn on is 150cm so that the alarm will warn the driver if the distance is less than that length. Based on the Figure , at 60kmph (16.6667ms^{-1}), the motorcycle is in the SRF04 ultrasonic region at that position is from t=3 to t=12. The distance measured by the sensor starts decreasing at t=3.Since the sampling time is every 20ms therefore,

$$(12 - 3) \times 20ms = 0.18\ seconds$$

The motorcycle is in the region of the sensor for 0.18 seconds.

Since the distance set for the alarm will turn on if the distance is less than 150cm, alarm is turned on in the region between t=3.3 and t=11.7. Since the sampling time is every 20ms,

$$(11.7 - 3.3) \times (20ms) = 0.168\ seconds$$

Thus, the alarm is on for 0.168 seconds.

Therefore, the difference between the time of that motorcycle in the region of the SRF04 ultrasonic sensor and the region which is set 150cm is:

$$0.18\ seconds - 0.168\ seconds = 0.012\ seconds$$

Sensor position: Under side mirror (Slant 45º)

Speed of motorcycle passing by the sensor: 20kmph (5.5556ms^{-1}).

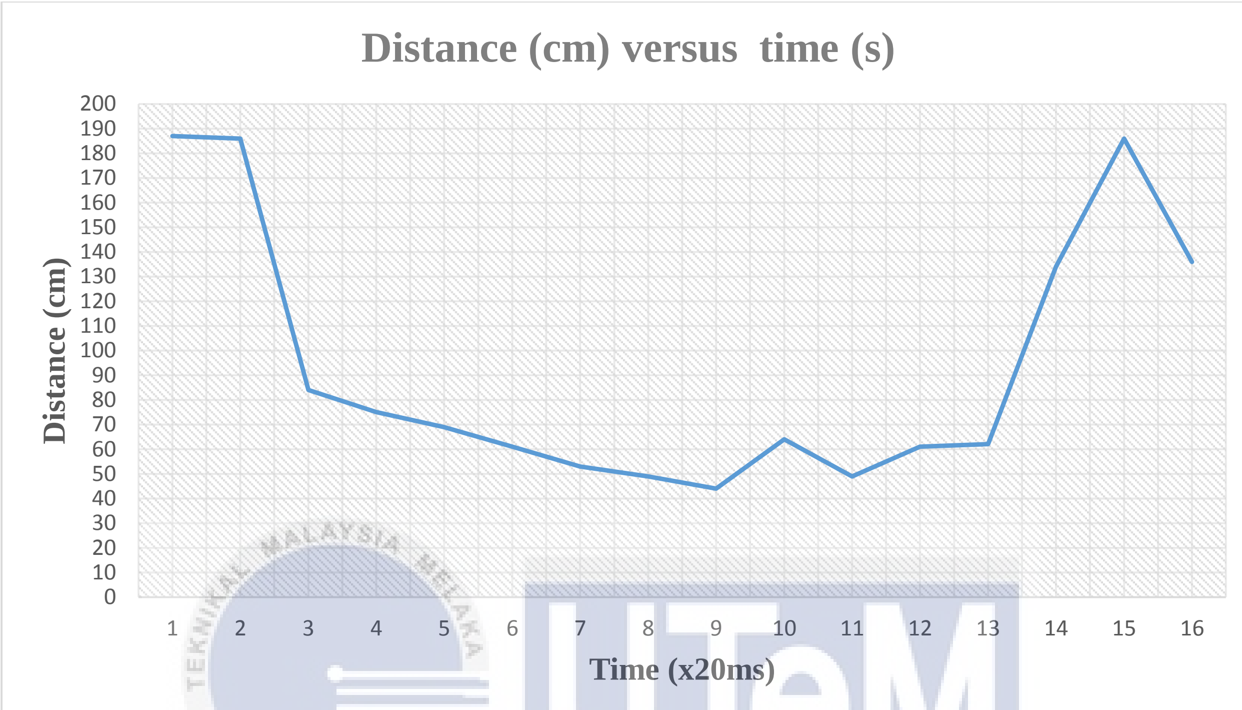

Figure 4.2: Graph of measured distance over time for motorcyle moving at 20kmph (16.6667ms^{-1})

Figure 4.2 shows the data taken for the sensor which is positioned under the side mirror and is slanted 45º towards the rear side of the car. The distance that has been set so that the alarm will turn on is 150cm so that the alarm will warn the driver if the distance is less than that length. Based on the Figure , at 20kmph (5.5556ms^{-1}), the motorcycle is in the SRF04 ultrasonic region that has been slanted for 45º is from t=3 to t=8. The distance measured by the sensor starts decreasing at t=2.Since the sampling time is every 20ms therefore,

$$(15 - 2) \times 20ms = 0.26\ seconds$$

The motorcycle is in the region of the sensor for 0.26 seconds.

Since the distance set for the alarm will turn on if the distance is less than 150cm, alarm is turned on in the region between t=2.4 and t=14.4. Since the sampling time is every 20ms,

$$(14.4 - 2.4) \times (20ms) = 0.24\ seconds$$

Thus, the alarm is on for 0.24 seconds.

Therefore, the difference between the time of that motorcycle in the region of the SRF04 ultrasonic sensor and the region which is set 150cm is:

$$0.26\ seconds - 0.24\ seconds = 0.02\ seconds$$

Sensor position: Under side mirror (Slant 45º)

Speed of motorcycle passing by the sensor: 40kmph (11.1111ms^{-1}).

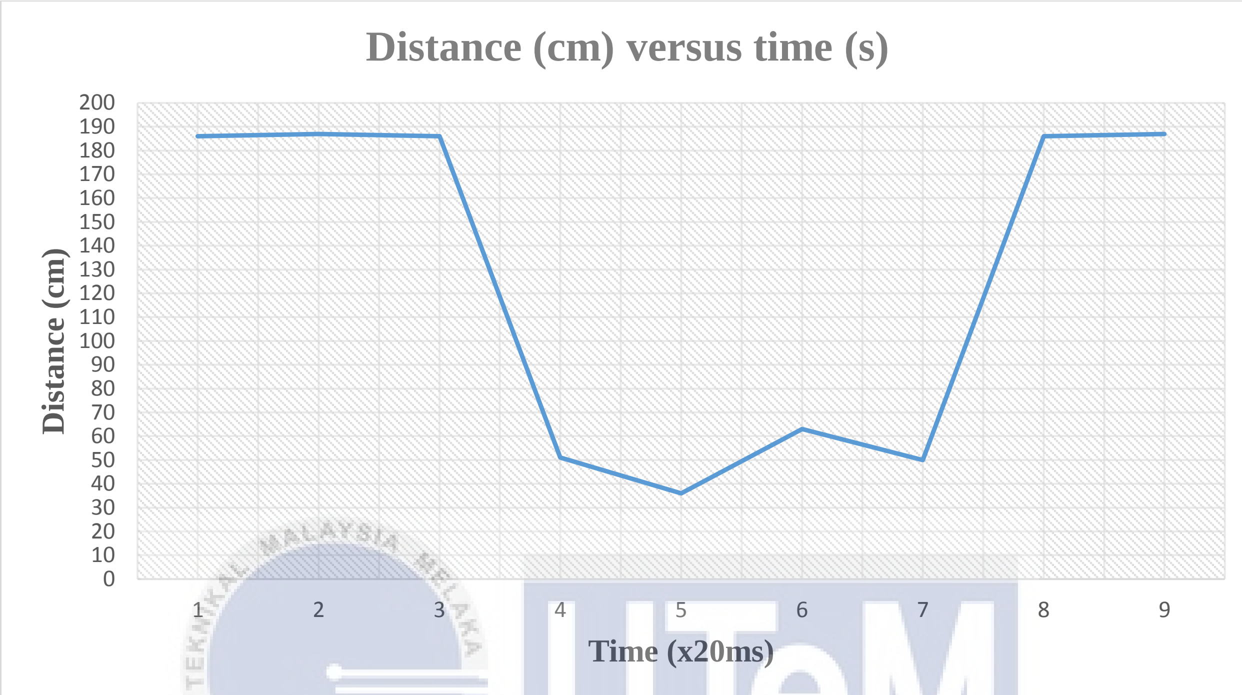

Figure 4.3: Graph of measured distance over time for motorcycle moving at 40kmph (11.1111ms^{-1})

Figure 4.3 shows the data taken for the sensor which is positioned under the side mirror and is slanted 45º towards the rear side of the car. The distance that has been set so that the alarm will turn on is 150cm so that the alarm will warn the driver if the distance is less than that length. Based on the Figure , at 40kmph (11.1111ms^{-1}), the motorcycle is in the SRF04 ultrasonic region that has been slanted for 45º is from t=3 to t=8. The distance measured by the sensor starts decreasing at t=3.Since the sampling time is every 20ms therefore,

$$(8-3) \times 20ms = 0.1\ seconds$$

The motorcycle is in the region of the sensor for 0.1 seconds.

Since the distance set for the alarm will turn on if the distance is less than 150cm, alarm is turned on in the region between t=3.3 and t=14.8. Since the sampling time is every 20ms,

$$(7.7 - 3.3) \times (20ms) = 0.088\ seconds$$

Thus, the alarm is on for 0.088 seconds.

Therefore, the difference between the time of that motorcycle in the region of the SRF04 ultrasonic sensor and the region which is set 150cm is:

$$0.1\ seconds - 0.088\ seconds = 0.012\ seconds$$

Sensor position: Under side mirror (Slant 45º)

Speed of motorcycle passing by the sensor: 60kmph (16.6667ms^{-1}).

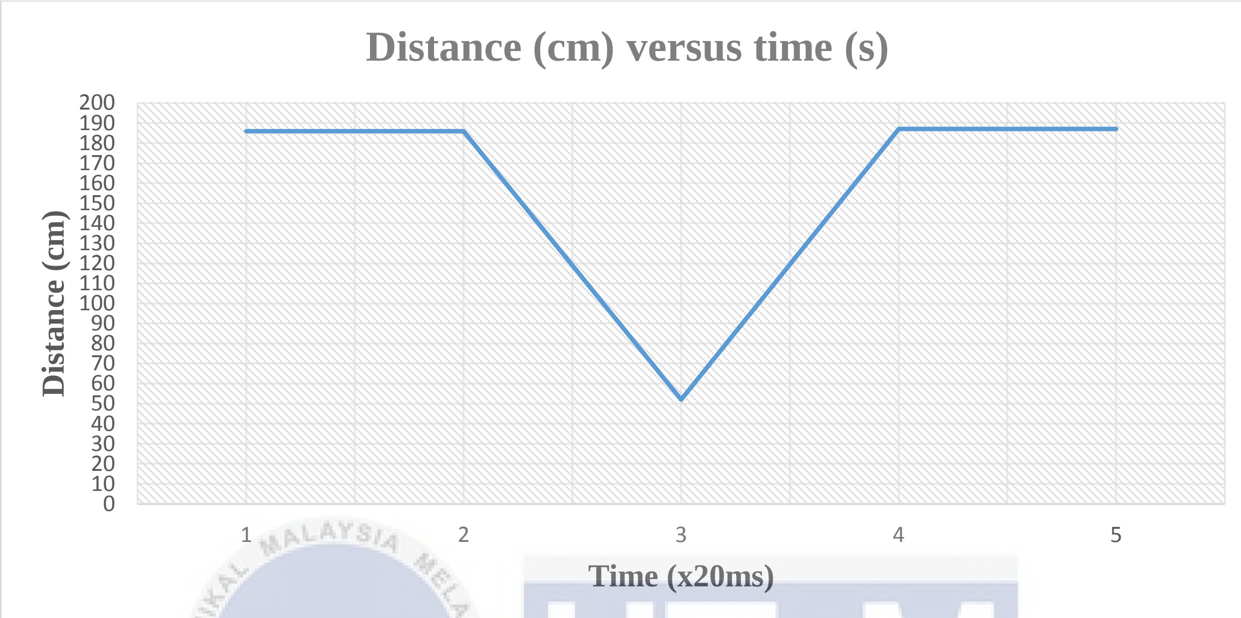

Figure 4.4: Graph of measured distance over time for motorcyle moving at 60kmph (16.6667ms^{-1})

Figure 4.4 shows the data taken for the sensor which is positioned under the side mirror and is slanted 45º towards the rear side of the car. The distance that has been set so that the alarm will turn on is 150cm so that the alarm will warn the driver if the distance is less than that length. Based on the Figure , at 60kmph (16.6667ms^{-1}), the motorcycle is in the SRF04 ultrasonic region that has been slanted for 45º is from t=3 to t=8. The distance measured by the sensor starts decreasing at t=3.Since the sampling time is every 20ms therefore,

$$(4-2) \times 20ms = 0.04\ seconds$$

The motorcycle is in the region of the sensor for 0.04 seconds.

Since the distance set for the alarm will turn on if the distance is less than 150cm, alarm is turned on in the region between t=2.3 and t=3.7. Since the sampling time is every 20ms,

$$(3.7 - 2.3) \times \ (20ms) = 0.028 \ seconds$$

Thus, the alarm is on for 0.028 seconds.

Therefore, the difference between the time of that motorcycle in the region of the SRF04 ultrasonic sensor and the region which is set 150cm is:

$$0.04 \ seconds - 0.028 \ seconds = 0.012 \ seconds$$

For the whole data of this experiment:

Table 4: Summary of the results obtained for sensor at static position

Speed		**Time (s)**	
(kmph)	**(ms^{-1})**	**Position: Above rear tire (A)**	**Position: Under side mirror (45° slant) (B)**
20	5.5556	0.312	0.24
40	11.1111	0.118	0.088
60	16.667	0.168	0.028

For the speed of the passing by motorcycle which is 20kmph (5.5556ms^{-1}), the difference of time for the alarm to turn on between the position above rear tire and under the side mirror is

$$0.312\ seconds - 0.24\ seconds = 0.072\ seconds$$

The time response of the system for the sensor positioned above the rear tire is 0.074 seconds longer compared to that under the side mirror. With A represents as the time for the position above the rear tire and B is for the time for under the side mirror,

$$\text{Difference in } \% = \left|\frac{A - B}{A}\right| \times 100$$

$$\text{Difference in } \% = \left|\frac{0.312 - 0.24}{0.312}\right| \times 100$$

$$\text{Difference in } \% = 23.08\%$$

The time for the sensor above the rear tire to respond is 23.08% longer and better compared that under the side mirror.

For the speed of the passing by motorcycle which is 40kmph (11.1111ms^{-1}), the difference of time for the alarm to turn on between the position above rear tire and under the side mirror is

$$0.118\ seconds - 0.088\ seconds = 0.03\ seconds$$

The time response of the system for the sensor positioned above the rear tire is 0.03 seconds longer compared to that under the side mirror. With A represents as the time for the position above the rear tire and B is for the time for under the side mirror,

$$\text{Difference in \%} = \left|\frac{\text{A} - \text{B}}{\text{A}}\right| \times 100$$

$$\text{Difference in \%} = \left|\frac{0.118 - 0.088}{0.118}\right| \times 100$$

$$\text{Difference in \%} = 25.42\%$$

The time for the sensor above the rear tire to respond is 25.42% longer and better compared that under the side mirror.

For the speed of the passing by motorcycle which is 60kmph (16.6667ms^{-1}), the difference of time for the alarm to turn on between the position above rear tire and under the side mirror is

$$0.168\ seconds - 0.028\ seconds = 0.14\ seconds$$

The time response of the system for the sensor positioned above the rear tire is 0.074 seconds longer compared to that under the side mirror. With A represents as the time for the position above the rear tire and B is for the time for under the side mirror,

$$\text{Difference in \%} = \left|\frac{\text{A} - \text{B}}{\text{A}}\right| \times 100$$

$$\text{Difference in \%} = \left|\frac{0.168 - 0.028}{0.168}\right| \times 100$$

$$\text{Difference in \%} = 83.33\%$$

The time for the sensor above the rear tire to respond is 83.38% longer and better compared that under the side mirror.

Theoretically, for the sensor at the position above the rear tire, the region of the sensor which the motorcycle will enter is as follows:

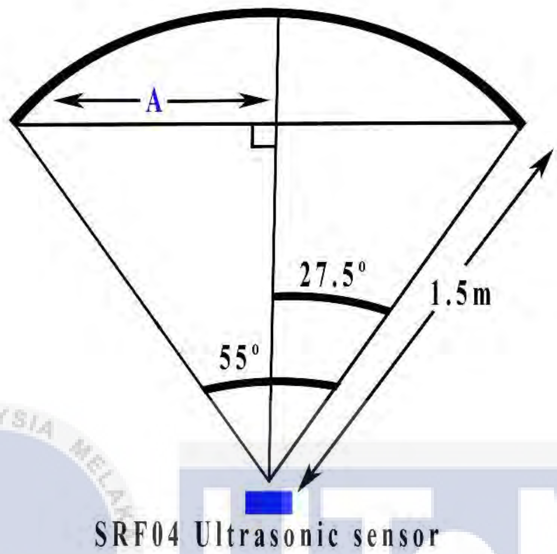

Figure 4.5: Region covered by sensor for position above rear tire.

$$\tan 27.5° = \frac{A}{1.5m}$$

$$1.5m \tan 27.5° = A$$

$$A = 0.7809m$$

$$2A = 2(0.7809m)$$

$$2A = 1.5618\text{m}$$

At the distance of 1.5m, the distance that the sensor able to cover is 1.5618m. Therefore, the system able to detect any incoming vehicle only within that region with the width of the angle of the region covered by the sensor is 55º.

Sensor position: Above rear tire

Speed of motorcycle passing by the sensor: 20kmph (5.5556ms^{-1}).

For the sensor is in static position and the motorcycle is passing by at a constant velocity of 20kmph (5.5556ms^{-1}), the time, t for the motorcycle is in the region covered by the sensor is as follows:

$$s = ut \tag{4.0}$$

Where s is the summation of the length of the length of the motorcycle and the length of the sensor that it able to cover is 2A, the time is calculated based on equation 4.0.

$$(2A + length\ of\ motorcycl)e = velocity\ of\ motorcycle \times time$$

$$(1.5618m + 1.889m) = (5.5556ms^{-1} \times t)$$

3.4508m=$(5.5556ms^{-1} \times t)$

$$\frac{3.4508m}{5.5556ms^{-1}} = t$$

$$t = 0.3524\ seconds$$

By comparing the theoretical value and the measure value, the percentage of error is obtained:

$$error\% = \left|\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right| \times 100$$

$$error\% = \left|\frac{0.3524\ seconds - 0.312s\ econds}{0.3524\ seconds}\right| \times 100$$

$$error\% = 4.11\%$$

The deviation of the measured value from the theoretical value is 4.11%.

Sensor position: Above rear tire

Speed of motorcycle passing by the sensor: 40kmph (11.1111ms^{-1}).

For the sensor is in static position and the motorcycle is passing by at a constant velocity of 40kmph (11.1111ms^{-1}), the time, t for the motorcycle is in the region covered by the sensor is as follows where s is the summation of the length of the length of the motorcycle and the length of the sensor that it able to cover is 2A, the time is calculated based on equation 4.0:

$$2A + length\ of\ motorcycle = velocity\ of\ motorcycle \times time$$

$$(1.5618m + 1.889m) = (11.1111ms^{-1} \times t)$$

$$3.4508\text{m}=(11.1111ms^{-1} \times t)$$

$$\frac{3.4508m}{11.1111ms^{-1}} = t$$

$$t = 0.2029\ seconds$$

By comparing the theoretical value and the measure value, the percentage of error is obtained:

$$error\% = \left|\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right| \times 100$$

$$error\% = \left|\frac{0.2029\ seconds - 0.1880\ seconds}{0.2029\ seconds}\right| \times 100$$

$$error\% = 7.34\%$$

The deviation of the measured value from the theoretical value is 7.34%.

Sensor position: Above rear tire

Speed of motorcycle passing by the sensor: 60kmph ($16.6667ms^{-1}$).

For the sensor is in static position and the motorcycle is passing by at a constant velocity of 60kmph ($16.6667ms^{-1}$), the time, t for the motorcycle is in the region covered by the sensor is as follows where s is the summation of the length of the length of the motorcycle and the length of the sensor that it able to cover is 2A, the time is calculated based on equation 4.0:

$$2A + length\ of\ motorcycle = velocity\ of\ motorcycle \times time$$

$$(1.5618m + 1.889m) = (16.6667ms^{-1} \times t)$$

3.4508m=$(16.6667ms^{-1} \times t)$

$$\frac{3.4508m}{16.6667ms^{-1}} = t$$

$$t = 0.1890\ seconds$$

By comparing the theoretical value and the measure value, the percentage of error is obtained:

$$error\% = \left|\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right| \times 100$$

$$error\% = \left|\frac{0.1890\ seconds - 0.0168\ seconds}{0.1890\ seconds}\right| \times 100$$

$$error\% = 11.13\%$$

The deviation of the measured value from the theoretical value is 11.13%.

For the sensor at the position under the side mirror with 45º slant, the region of the sensor which the motorcycle will enter is as follows where C with the green colored line is the length of the region of the sensor where the motorcycle enters:

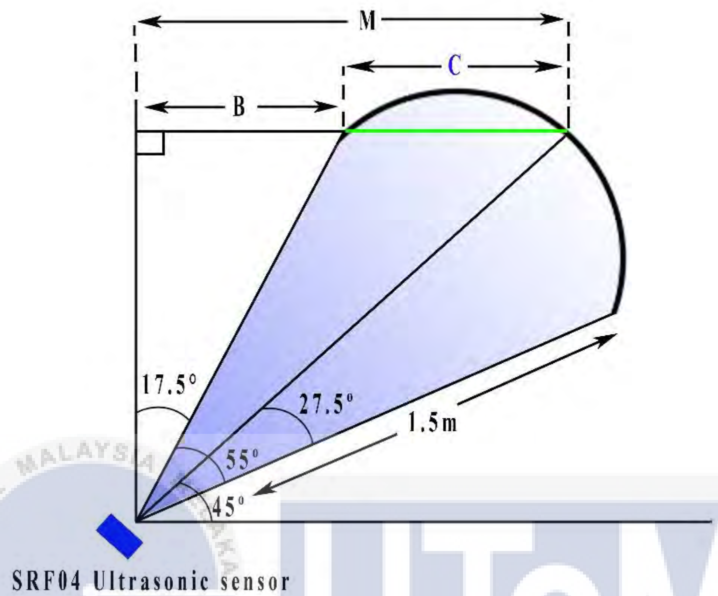

Figure 4.6: Region covered by sensor for position under side mirror with 45º slant.

$$\sin 27.5° = \frac{B}{1.5m}$$

$$B = 0.6926m$$

$$\sin 45° = \frac{M}{1.5m}$$

$$M = 1.0607m$$

$$Length\ C = Length\ M - LengthB$$

$$Length\ C = 1.0607m - 0.6926m$$

$$Length\ C = 0.3681m$$

At the distance of 1.5m with the sensor is 45º slant, the distance that the sensor able to cover is 0.3681m. Therefore, the system able to detect any incoming vehicle only within that region with the width of the angle of the region covered by the sensor is 27.5 º only.

Sensor position: Under side mirror (Slant 45°)

Speed of motorcycle passing by the sensor: 20kmph (5.5556ms^{-1}).

Where s is the summation of the length of the length of the motorcycle and the length of the sensor that it able to cover is C, the time is calculated based on equation 4.0.

$$C + length\ of\ motorcycle = velocity\ of\ motorcycle \times time$$

$$(0.3681m + 1.889m) = (5.5556ms^{-1} \times t)$$

$$2.2571m = (5.5556ms^{-1} \times t)$$

$$\frac{2.2571m}{5.5556ms^{-1}} = t$$

$$t = 0.2616\ seconds$$

By comparing the theoretical value and the measure value, the percentage of error is obtained:

$$error\% = \left|\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right| \times 100$$

$$error\% = \left|\frac{0.2616\ seconds - 0.24\ seconds}{0.2616\ seconds}\right| \times 100$$

$$error\% = 8.24\%$$

The deviation of the measured value from the theoretical value is 8.24%.

Sensor position: Under side mirror (Slant 45º)

Speed of motorcycle passing by the sensor: 40kmph ($11.1111ms^{-1}$).

Where s is the summation of the length of the length of the motorcycle and the length of the sensor that it able to cover is C, the time is calculated based on equation 4.0.

$$C + length\ of\ motorcycle = velocity\ of\ motorcycle \times time$$

$$(0.3681m + 1.889m) = (5.5556ms^{-1} \times t)$$

$$2.2571m = (11.1111ms^{-1} \times t)$$

$$\frac{2.2571m}{11.1111ms^{-1}} = t$$

$$t = 0.0997\ seconds$$

By comparing the theoretical value and the measure value, the percentage of error is obtained:

$$error\% = \left|\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right| \times 100$$

$$error\% = \left|\frac{0.0997\ seconds - 0.088\ seconds}{0.0997\ seconds}\right| \times 100$$

$$error\% = 11.74\%$$

The deviation of the measured value from the theoretical value is 11.74%.

Sensor position: Under side mirror (Slant 45º)

Speed of motorcycle passing by the sensor: 60kmph ($16.6667ms^{-1}$).

Where s is the summation of the length of the length of the motorcycle and the length of the sensor that it able to cover is C, the time is calculated based on equation 4.0.

$$C + length\ of\ motorcycle = velocity\ of\ motorcycle \times time$$

$$(0.3681m + 1.889m) = (16.6667ms^{-1} \times t)$$

$$2.2571m = (16.6667ms^{-1} \times t)$$

$$\frac{2.2571m}{16.6667ms^{-1}} = t$$

$$t = 0.0327\ seconds$$

By comparing the theoretical value and the measure value, the percentage of error is obtained:

$$error\% = \left|\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right| \times 100$$

$$error\% = \left|\frac{0.0327\ seconds - 0.028\ seconds}{0.0327\ seconds}\right| \times 100$$

$$error\% = 14.44\%$$

The deviation of the measured value from the theoretical value is 14.44%.

The error of the measured values for both position above rear tire and under side mirror with 45º slant is summarized as follows:

Table 5: Summary of the results and error obtained for sensor is in static condition and motorcycle moving at a constant velocity

Speed (kmph)	**Position**					
	Above rear tire			**Under side mirror (45º slant)**		
	Theoretical value (s)	**Measured value (s)**	**Error (%)**	**Theoretical value (s)**	**Measured value (s)**	**Error (%)**
20	0.3254	0.312	4.11	0.2616	0.2400	8.24
40	0.2029	0.1880	7.34	0.0997	0.0880	11.74
60	0.1890	0.1680	11.13	0.0327	0.0280	14.44

It is clear that the error for the sensor at position under the side mirror with 45º slant is higher compared to that above the rear tire.

4.3 Experiment 3:

The purpose of this experiment is to make an analysis on the time response of the system with two different position of the sensor which is above the rear tire and under the side mirror with 45º slant with the sensor is moving at certain constant velocity. The data are as follows:

Sensor position: Above rear tire

Speed of motorcycle passing by the sensor: 20kmph ($5.5556ms^{-1}$).

Speed of the sensor on the car: 40kmph ($11.1111ms^{-1}$).

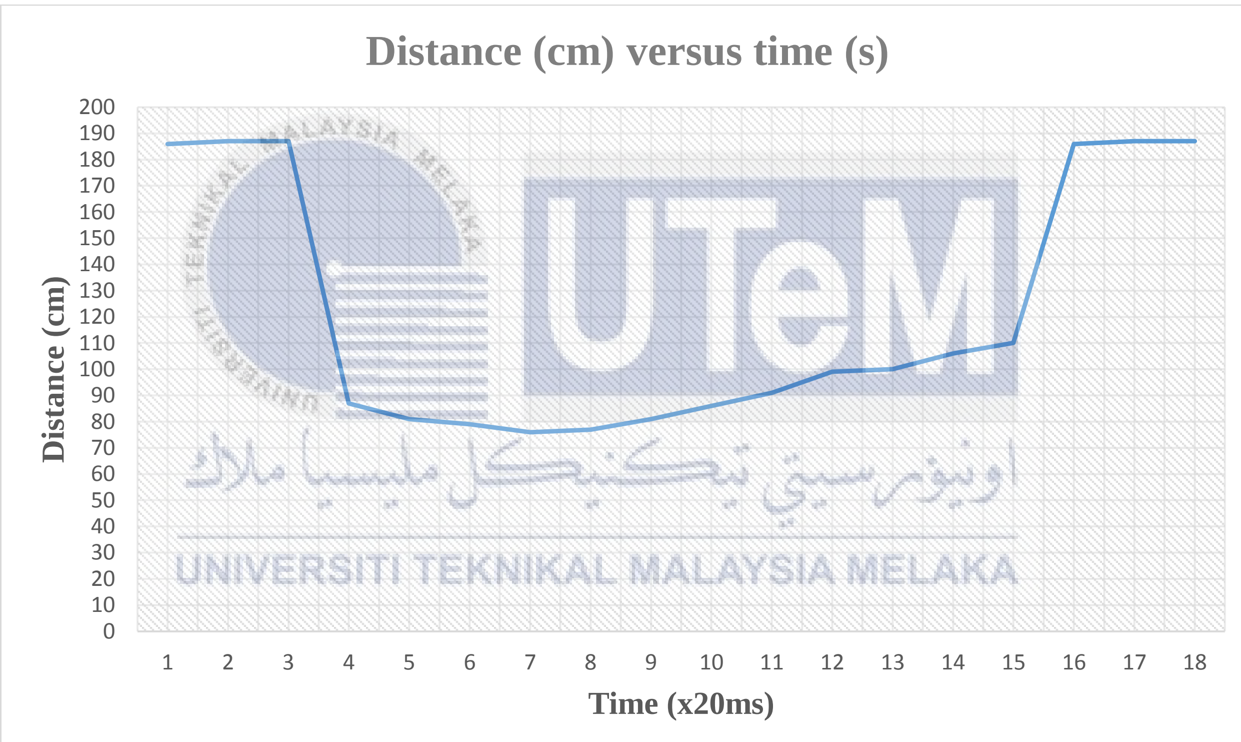

Figure 4.7: Graph of measured distance over time for sesnor moving at 20kmph ($5.5556ms^{-1}$) and motorcyle moving at 40kmph ($16.6667ms^{-1}$)

Figure 4.5 shows the data taken for the sensor which is positioned above rear tire and it is pointing outwards. The distance that has been set so that the alarm will turn on is 150cm so that the alarm will warn the driver if the distance is less than that length. The sensor which is mounted is moving at constant velocity of at 20kmph ($5.5556ms^{-1}$) while the motorcycle is passing by the sensor at 40kmph ($11.1111ms^{-1}$).

Based on the Figure 4.5, at the movement speed of the sensor which is 20kmph ($5.5556ms^{-1}$) and the motorcycle is passing by the sensor at 40kmph ($11.1111ms^{-1}$), the motorcycle is in the SRF04 ultrasonic region at that position is from t=3 to t=16. The distance measured by the sensor starts decreasing at t=3.Since the sampling time is every 20ms therefore,

$$(16 - 3) \times 20ms = 0.26\ seconds$$

The motorcycle is in the region of the sensor for 0.26 seconds.

Since the distance set for the alarm will turn on if the distance is less than 150cm, alarm is turned on in the region between t=3.4 and t=15.6. Since the sampling time is every 20ms,

$$(15.6 - 3.4) \times\ (20ms) = 0.244\ seconds$$

Thus, the alarm is on for 0.244 seconds.

Therefore, the difference between the time of that motorcycle in the region of the SRF04 ultrasonic sensor and the region which is set 150cm is:

$$0.26\ seconds - 0.244\ seconds = 0.016\ seconds$$

Sensor position: Above rear tire

Speed of motorcycle passing by the sensor: 40kmph (11.1111ms^{-1}).

Speed of the sensor on the car: 60kmph (16.6667ms^{-1}).

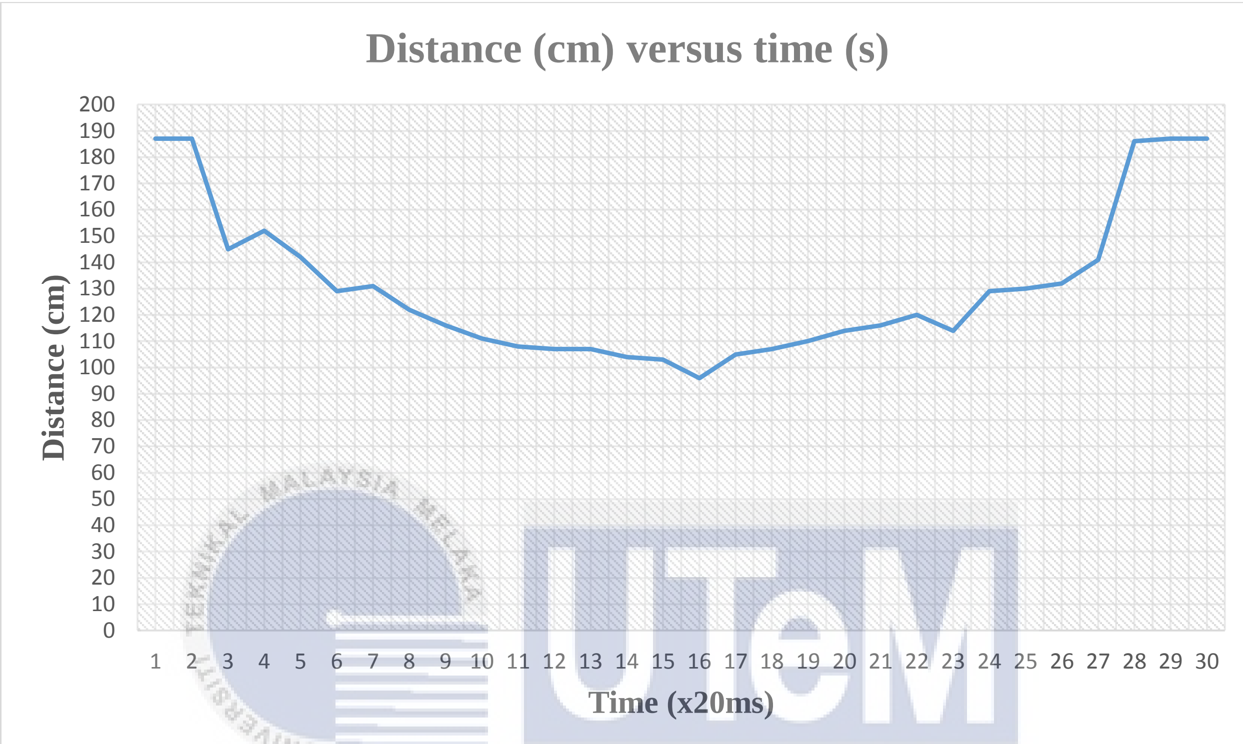

Figure 4.6: Graph of measured distance over time for sesnor moving at 40kmph (11.1111ms^{-1}) and motorcyle moving at 60kmph (16.6667ms^{-1})

Figure shows the data taken for the sensor which is positioned above rear tire and it is pointing outwards. The distance that has been set so that the alarm will turn on is 150cm so that the alarm will warn the driver if the distance is less than that length. The sensor which is mounted is moving at constant velocity of at 40kmph (11.1111ms^{-1}) while the motorcycle is moving at 60kmph (16.6667ms^{-1}), Based on the Figure , at the speed of the sensor of 40kmph (11.1111ms^{-1}) and the motorcycle is passing by the sensor at 60kmph (16.6667ms^{-1}), the motorcycle is in the SRF04 ultrasonic region at that position is from t=2 to t=28. The distance measured by the sensor starts decreasing at t=2.Since the sampling time is every 20ms therefore,

$$(28 - 2) \times 20ms = 0.52\ seconds$$

The motorcycle is in the region of the sensor for 0.52 seconds.

Since the distance set for the alarm will turn on if the distance is less than 150cm, alarm is turned on in the region between t=2.9 and t=27.3. Since the sampling time is every 20ms,

$$(27.3 - 4.5) \times \ (20ms) = 0.456\ seconds$$

Thus, the alarm is on for 0.456 seconds.

Therefore, the difference between the time of that motorcycle in the region of the SRF04 ultrasonic sensor and the region which is set 150cm is:

$$0.52\ seconds - 0.456\ seconds = 0.064\ seconds$$

Sensor position: Under side mirror (Slant 45º)

Speed of motorcycle passing by the sensor: 20kmph (5.5556ms^{-1}).

Speed of the sensor on the car: 40kmph (11.1111ms^{-1}).

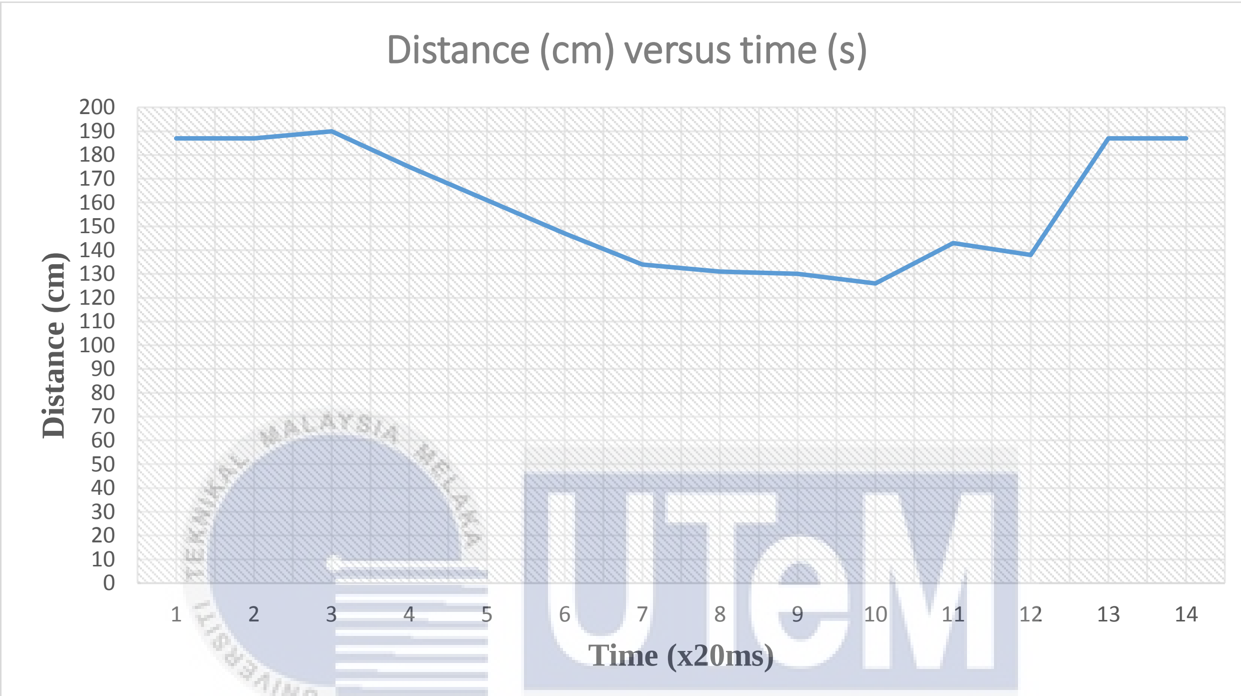

Figure 4.7: Graph of measured distance over time for sesnor moving at 40kmph (11.1111ms^{-1}) and motorcycle moving at 60kmph (16.6667ms^{-1})

Figure 4.7 shows the data taken for the sensor which is positioned under the side mirror and it is slanted 45º towards the rear side of the car. The distance that has been set so that the alarm will turn on is 150cm so that the alarm will warn the driver if the distance is less than that length. The sensor which is mounted is moving at constant velocity of at 20kmph (5.5556ms^{-1}) while the motorcycle is moving at 40kmph (11.1111ms^{-1}). Based on the Figure , at the speed of the sensor of 20kmph (5.5556ms^{-1}) and the motorcycle is passing by the sensor at 40kmph (11.1111ms^{-1}), the motorcycle is in the SRF04 ultrasonic region at that position is from t=3 to t=13. The distance measured by the sensor starts decreasing at t=3.Since the sampling time is every 20ms therefore,

$$(13 - 3) \times 20ms = 0.2\ seconds$$

The motorcycle is in the region of the sensor for 0.2 seconds.

Since the distance set for the alarm will turn on if the distance is less than 150cm, alarm is turned on in the region between t=5.7 and t=12.3. Since the sampling time is every 20ms,

$$(12.3 - 5.7) \times (20ms) = 0.132\ seconds$$

Thus, the alarm is on for 0.132 seconds.

Therefore, the difference between the time of that motorcycle in the region of the SRF04 ultrasonic sensor and the region which is set 150cm is:

$$0.2\ seconds - 0.132\ seconds = 0.068\ seconds$$

Sensor position: Under side mirror (Slant 45º)

Speed of motorcycle passing by the sensor: 40kmph ($11.1111ms^{-1}$).

Speed of the sensor on the car: 60kmph ($16.6667ms^{-1}$).

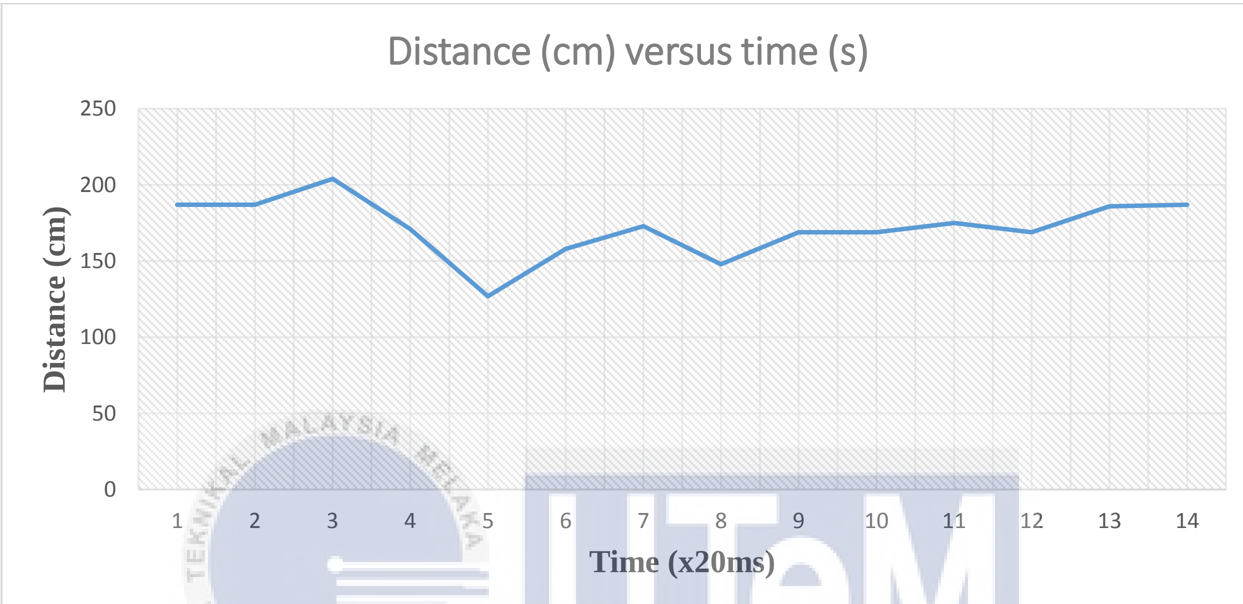

Figure 4.8: Graph of measured distance over time for sesnor moving at 40kmph ($11.1111ms^{-1}$) and motorcyle moving at 60kmph ($16.6667ms^{-1}$)

Figure 4.8 shows the data taken for the sensor which is positioned under the side mirror and it is slanted 45º towards the rear side of the car. The distance that has been set so that the alarm will turn on is 150cm so that the alarm will warn the driver if the distance is less than that length. The sensor which is mounted is moving at constant velocity of at 40kmph ($11.1111ms^{-1}$) while the motorcycle is passing by the car at 60kmph ($16.6667ms^{-1}$). Based on the Figure , at the moving speed of the sensor of 40kmph ($11.1111ms^{-1}$) and the motorcycle is passing by the sensor at 60kmph ($16.6667ms^{-1}$), the motorcycle is in the SRF04 ultrasonic region at that position is from t=3 to t=13. The distance measured by the sensor starts decreasing at t=4.4.Since the sampling time is every 20ms therefore,

$$(13 - 3) \times 20ms = 0.2\ seconds$$

The motorcycle is in the region of the sensor for 0.2 seconds.

Since the distance set for the alarm will turn on if the distance is less than 150cm, alarm is turned on in the region between t=4.4 and t=8. Since the sampling time is every 20ms,

$$(8 - 4.4) \times \ (20ms) = 0.072\ seconds$$

Thus, the alarm is spuppposed to be on for 0.072 seconds.

The reading is above 150cm between t=5.7 and t=7.8 it fluctuate back.

$$(7.8 - 5.7) \times 20ms = 0.042\ seconds$$

The alarm is paused for 0.042 seconds.

$$0.072\ seconds - 0.042\ seconds = 0.03\ seconds$$

Therefore, the actual time for the alram to turned on is 0.03 seconds. There could be disturbance during the measurement.

For the whole data of this experiment:

Table 6: Summary of the experiment for both car and motorcycle moving at a constant velocity

Speed				**Time (s)**	
Car		**Motorcycle**		**Position: Above rear tire**	**Position: Under side mirror**
(kmph)	**ms^{-1}**	**(kmph)**	**ms^{-1}**		
20	5.5556	40	11.1111	0.244	0.132
40	11.1111	60	16.6667	0.488	0.072

For the speed of the moving sensor at 20kmph (5.5556ms^{-1}) and the passing by motorcycle which is 40kmph (11.1111ms^{-1}), the difference of time for the alarm to turn on between the position above rear tire and under the side mirror is

$$0.244\ seconds - 0.132\ seconds = 0.112\ seconds$$

The time response of the system when moving at constant velocity of 20kmph (5.5556ms^{-1}) and the passing by motorcycle at 40kmph (11.1111ms^{-1}) for which the sensor positioned above the rear tire is 0.077 seconds longer compared to that under the side mirror. With A represents as the time for the position above the rear tire and B is for the time for under the side mirror,

$$\text{Difference in } \% = \left|\frac{A - B}{A}\right| \times 100$$

$$\text{Difference in } \% = \left|\frac{0.244 - 0.132}{0.244}\right| \times 100$$

$$\text{Difference in } \% = 23.08\%$$

The time for the sensor above the rear tire to respond is 45.90% longer and better compared that under the side mirror.

For the speed of the moving sensor at 40kmph (11.1111ms^{-1}) and the passing by motorcycle which is 60kmph (16.6667ms^{-1}), the difference of time for the alarm to turn on between the position above rear tire and under the side mirror is

$$0.488\ seconds - 0.072\ seconds = 0.416\ seconds$$

The time response of the system when moving at constant velocity of 20kmph (5.5556ms^{-1}) and the passing by motorcycle at 40kmph (11.1111ms^{-1}) for which the sensor positioned above the rear tire is 0.077 seconds longer compared to that under the side mirror. With A represents as the time for the position above the rear tire and B is for the time for under the side mirror,

$$\text{Difference in \%} = \left|\frac{\text{A} - \text{B}}{\text{A}}\right| \times 100$$

$$\text{Difference in \%} = \left|\frac{0.488 - 0.072}{0.488}\right| \times 100$$

$$\text{Difference in \%} = 85.248\%$$

The time for the sensor above the rear tire to respond is 85.24% longer and better compared that under the side mirror.

The time for which the motorcycle in the region of the sensor will respond and the alarm the driver is as in the equation 4.1 below:

$$s = ut + \frac{1}{2}at^2 \tag{4.1}$$

Where s is the summation the length of the motorcycle and the length of the sensor that it able to cover, C and a is the acceleration of the motorcycle. Whereas u is the velocity and t is the time of the motorcycle in the length C. Since the motorcycle is moving at a constant velocity, therefore, the acceleration, a is equals to zero. Thus, equation 4.2 is obtained.

$$s = ut \tag{4.2}$$

Since s is the summation of the of the length of the motorcycle and the length of the sensor that it able to cover, C,

$$(C + length\ of\ motorcycle) = (difference\ in\ velocity \times time) \tag{4.3}$$

Sensor position: Above rear tire

Speed of motorcycle passing by the sensor: 20kmph ($5.5556ms^{-1}$).

Speed of the sensor on the car: 40kmph ($11.1111ms^{-1}$).

For the both the sensor above the rear tire and the motorcycle that is passing by moving forward at a constant velocity of 20kmph ($5.5556ms^{-1}$) and 40kmph ($11.1111ms^{-1}$, the time, t for the motorcycle is in the region covered by the sensor is as follows which is based on equation 4.3:

$$(C + length\ of\ motorcycle) = (difference\ in\ velocity \times time)$$

$$(0.3681m + 1.889m) = (11.1111ms^{-1} - 5.5556ms^{-1}) \times t$$

$$(2.2571) = (5.5555ms^{-1}) \times t$$

$$t = 0.2817ms^{-1}$$

By comparing the theoretical value and the measure value, the percentage of error is obtained:

$$error\% = \left|\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right| \times 100$$

$$error\% = \left|\frac{0.2817\ seconds - 0.2440\ seconds}{0.2817\ seconds}\right| \times 100$$

$$error\% = 13.38\%$$

Therefore, the deviation of the measured value from the theoretical value is 13.38%.

Sensor position: Above rear tire

Speed of motorcycle passing by the sensor: 40kmph (11.1111ms^{-1}).

Speed of the sensor on the car: 60kmph (16.6667ms^{-1}).

For the both the sensor on the above the rear tire and the motorcycle that is passing by moving forward at a constant velocity of 40kmph (11.1111ms^{-1}) and 60kmph (16.6667ms^{-1}, the time, t for the motorcycle is in the region covered by the sensor is as follows which is based on equation 4.3:

$$(C + length\ of\ motorcycle) = (difference\ in\ velocity \times time)$$
$$(0.3681m + 1.889m) = (16.6667ms^{-1} - 11.1111ms^{-1}) \times t$$
$$(2.2571) = (5.5556ms^{-1}) \times t$$
$$t = 0.5449ms^{-1}$$

By comparing the theoretical value and the measure value, the percentage of error is obtained:

$$error\% = \left|\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right| \times 100$$
$$error\% = \left|\frac{0.5449\ seconds - 0.4560\ seconds}{0.5449\ seconds}\right| \times 100$$
$$error\% = 16.31\%$$

Therefore, the deviation of the measured value from the theoretical value is 16.31%.

Sensor position: Under side mirror (Slant 45º)

Speed of motorcycle passing by the sensor: 20kmph ($5.5556ms^{-1}$).

Speed of the sensor on the car: 40kmph ($11.1111ms^{-1}$).

For the both the sensor on the car which is slanted 45º and the motorcycle that is passing by moving forward at a constant velocity of 20kmph ($5.5556ms^{-1}$) and 40kmph ($11.1111ms^{-1}$, the time, t for the motorcycle is in the region covered by the sensor is as follows which is based on equation 4.3:

$$(C + length\ of\ motorcycle) = (difference\ in\ velocity \times time)$$
$$(0.3681m + 1.889m) = (11.1111ms^{-1} - 5.5556ms^{-1}) \times t$$
$$(2.2571) = (5.5555ms^{-1}) \times t$$
$$t = 0.1584ms^{-1}$$

By comparing the theoretical value and the measure value, the percentage of error is obtained:

$$error\% = \left|\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right| \times 100$$
$$error\% = \left|\frac{0.1584\ seconds - 0.132\ seconds}{0.1584\ seconds}\right| \times 100$$
$$error\% = 16.67\%$$

Therefore, the deviation of the measured value from the theoretical value is 16.67%.

Sensor position: Under side mirror (Slant 45º)

Speed of motorcycle passing by the sensor: 40kmph ($11.1111ms^{-1}$).

Speed of the sensor on the car: 60kmph ($16.6667ms^{-1}$).

For the both the sensor on the car which is slanted 45º and the motorcycle that is passing by moving forward at a constant velocity of 40kmph ($11.1111ms^{-1}$) and 60kmph ($16.6667ms^{-1}$), the time, t for the motorcycle is in the region covered by the sensor is as follows which is based on equation 4.3:

$$(C + length\ of\ motorcycle) = (difference\ in\ velocity \times time)$$
$$(0.3681m + 1.889m) = (16.6667ms^{-1} - 11.1111ms^{-1}) \times t$$
$$(2.2571) = (5.5556ms^{-1}) \times t$$
$$t = 0.20877ms^{-1}$$

By comparing the theoretical value and the measure value, the percentage of error is obtained:

$$error\% = \left|\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right| \times 100$$
$$error\% = \left|\frac{0.0877\ seconds - 0.072\ seconds}{0.0877\ seconds}\right| \times 100$$
$$error\% = 17.86\%$$

Therefore, the deviation of the measured value from the theoretical value is 17.86%.

The error of the measured values for both position above rear tire and under side mirror with 45º slant is summarized as follows:

Table 7: Summary of error for both sensor on car and motorcycle are moving with constant velocity.

Speed		**Position**					
Sensor on car (kmph)	**Motorcycle (kmph)**	**Above rear tire**			**Under side mirror (45º slant)**		
		Theoretical value (s)	**Measured value (s)**	**Error (%)**	**Theoretical value (s)**	**Measured value (s)**	**Error (%)**
20	40	0.2817	0.2440	13.38	0.1584	0.1320	16.67
40	60	0.5449	0.456	16.31	0.0877	0.0720	17.86

It is clear that the error for the sensor at position under the side mirror with 45º slant is higher compared to that above the rear tire.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In this section, the conclusion and recommendation for this project will be presented. The conclusion is discuss about the progress of this project which is based on the objective that has been decided in chapter 1. The continuation and implementation of the vehicles blind spot detection and warning system is discussed in the recommendation part.

5.1 Conclusion

The first objective which is to develop and implement a device that will warn the driver about the incoming vehicles in the blind spot area by blinking LED is achieved. The device has been implemented and tested with different speed for different speed of approaching vehicle. The development of the system by using Arduino microcontroller and ultrasonic sensor is done. The second objective which is to analyze the system in terms of range and position of the sensor is achieved. The sensor also have good performance at certain distance with certain range. Based on the results that has been obtained through the experiments, it is proven that the position of the sensor above the rear tire is better than that under the side mirror as the time of the alarm is longer so that the driver will able to notice the incoming vehicle. For both sensor is in static condition and moving at constant velocity, the percentage of error of the sensor if it is located under the side mirror (45º slant)

5.2 Recommendation

For further studies and experiment, the system can be improved by using more than one ultrasonic sensor at one time so that the area of the blind spot area can be covered more and the response will be better. The warning system can also be improved by replacing the blinking LED with a motor which will rotate once the incoming vehicle is detected. The motor is implemented inside the steering wheel so that the driver will be able to feel the vibration once any vehicle approaches in the blind spot area when driving.

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