An Analysis of Sensor Placement for Vehicle's Blind Spot Detection and Warning System

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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 study 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 investigate the effectiveness of the system in terms of the position of the sensor used for the system. The developed system are equipped with an Arduino UNO microcontroller and SRF04 ultrasonic sensor. There are two experiments be conducted. The first experiment is carried out to make an analysis on the time response of the system with position of the sensor above the rear tire of the static vehicle. The second experiment is carried out to examine the time response of the system with same position of the sensor with the moving vehicle at certain constant velocity. The result shows that the sensor placement above the rear tire give a good performance in term of driver notification of the presence of vehicle at the blind spot region.**

***Index Terms*— Blind Spot; Detection System; Smart Vehicle; Ultrasonic Sensor.**

I. INTRODUCTION

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.

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. 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 blind spot area is still not wide enough to cover the whole blind spot area. Therefore, an increasing number of research were conducted year by year to overcome those issues [7-13].

The main goal 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. Later, the effectiveness of sensor's position is be analyzed. The organization of the paper are as follows. Section II presents the methods consider in the research including the hardware selection, positioning, calculation and experimental procedure. While, Section III presents the experimental results and its discussion. Finally, Section IV concludes the outcome of this paper.

II. METHODOLOGY

In this section, 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 experimental procedure that has been conducted.

The view of the car driver is very limited because of the designed structure of the car. It is very difficult for the driver to see the unexpected coming object at the blind spot area. Figure 1 shows a blind spot region of the car driver's view. Apart than the side mirrors, this study proposes to mount a sensor at the area that can covers or detects the presence of any objects at the blind spot region. The system is called as Vehicle Blind Spot Detection and Warning System. Thus, the detection system is proposed to be placed at the area of above the rear tire as depicted in Figure 2 and Figure 3. It will give the indication to the driver on the presence of the object or vehicle at the blind spot region.

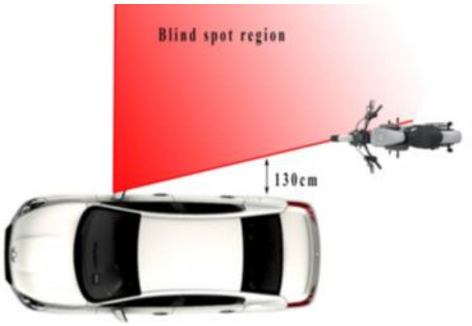


Figure 1: Blind spot region of the car's driver

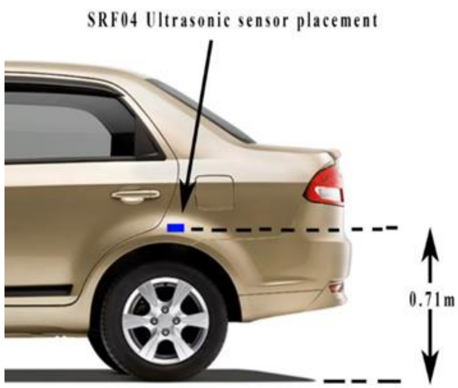


Figure 2: Side view of sensor placement for above rear tire

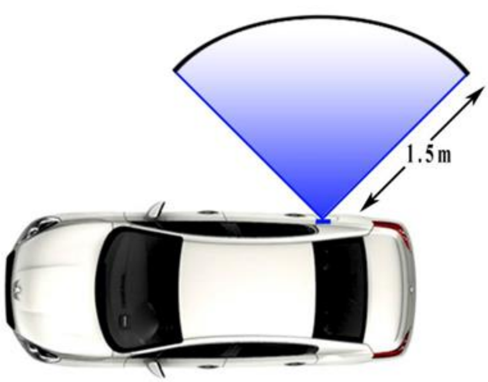


Figure 3: Top view of sensor placement for above the rear tire and the range covered

Theoretically, based on the Figure 4, for the sensor at the position above the rear tire, the region of the sensor which the object will enter is as follows:

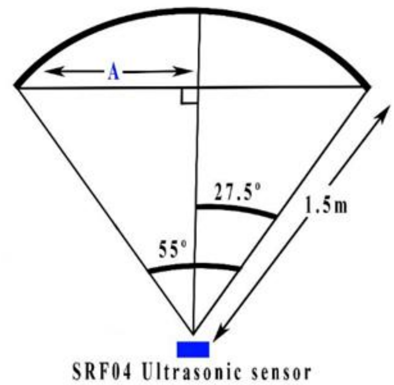


Figure 4: Region covered by sensor for position above rear tire

$$\text{Sin } 27.5° = A/1.5m$$
$$1.5m \text{ x Sin } 27.5° = A$$
$$A = 0.6926m$$
$$2A = 2 \text{ x } 0.6926m$$
$$2A = 1.3852m$$

At the sensor cover distance of $1.5m$, the longitudinal distance that the sensor able to cover is $1.3852m$. 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 which is 55º.

A. System Development

The system are encompasses of the microcontroller and a sensor. 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 5 depicts the Arduino UNO which based on the ATmega328P microcontroller's architecture.

Figure 5: Arduino UNO [14]

In this study, the SRF04 ultrasonic sensor is chosen as to measure the distance. Camera is not chosen because of its complexity of the algorithm and requires more time and cost to be developed. 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. The SRF04 may produce the Polaroid sonar which requires a short trigger pulse and providing an echo pulse which is proportional to the distance. To obtain the reading in centimeters (cm), the method presented in [15] can be used, where the width of the pulse is measured in micro-seconds (µs) and then is divided by 58. Figure 6 shows the SRF04 ultrasonic sensor. The system also involving other electronic component which are light emitting diode (LED) and 16 X 2 led display.

Figure 6: SRF04 Ultrasonic sensor [15]

Figure 7 shows the process flow chart of the operation of the vehicle blind spot detection and warning system. Once the system is switched 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 led display. Otherwise, it will continue measuring the distance and "Blind spot system running" will be displayed. If the measured distance is less than the set value, the system will alert the driver.

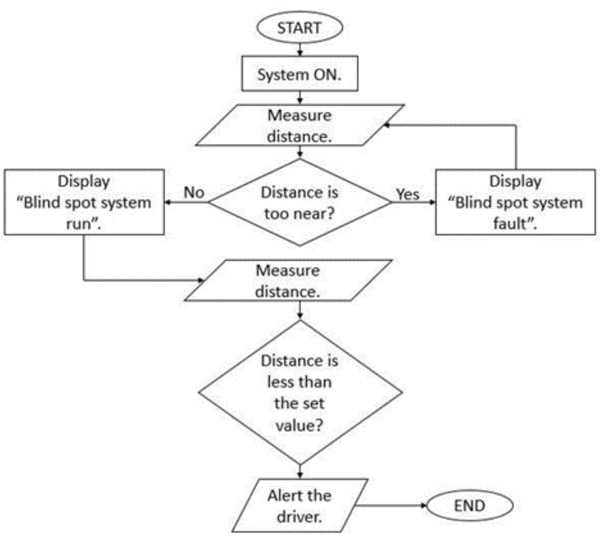


Figure 7: Process flow chart of the system

B. Experimental Procedure

In this study, there are two types of experiments. The first experiment with the condition of static car and the second experiment with the condition of moving car.

a. Experiment 1

For the first experiment, it is conducted to analyse the response of the system towards the incoming vehicle in the blind spot area with the sensor at static position (not moving car). A motorcycle (1.889m length and 0.706m width) is used as for the detection coming object. The distance for the alarm to turn on when the incoming object is detected is set to the distance of 150cm. 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 8.

Figure 8: Sensor above the rear tire

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 9. 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. The experimental process is repeated with the velocity of the passing by motorcycle is 40kmph ($11.1111ms^{-1}$) and 60kmph ($16.6.6667ms^{-1}$). The selected 20kmph, 40kmph and 60kmph of speed were chosen as a sample speed for this study.

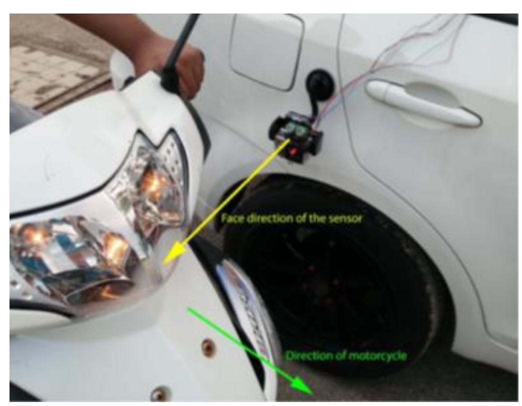


Figure 9: Face direction of the sensor and the direction of motorcycle

b. Experiment 2

For the second experiment, it is conducted to analyse the respond of the system towards the incoming vehicle in the blind spot area with the sensor is moving certain velocity. The experiment uses the same procedures as in Experiment 1 but with the condition of moving car. 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 ($11.1111ms^{-1}$). The data is collected from the serial monitor of the Arduino software which the sampling time is 20ms. The experiment is repeated with the speed of the sensor (car) is at 40kmph ($11.1111ms^{-1}$) and the speed of the motorcycle is at 70kmph ($19.4444ms^{-1}$).

C. Theoretical Calculation

For the sensor that is in static position and the motorcycle is passing by at a constant velocity, the time, *t* for the motorcycle in the region covered by the sensor is as follows:

$$s = ut \tag{1}$$

where, *s*, is the summation of the length of the motorcycle and the length of the sensor that is able to cover, which is 2A. Hence, the time is calculated based on Equation (2).

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

For the sensor with the condition of moving car, the time for which the motorcycle in the region of the sensor is calculated as in the Equation (3):

$$s = ut + (1/2)\ at^2 \tag{3}$$

where, *s*, is the summation of the motorcycle length and the length of the sensor area covered, *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 (1) can be used for the calculation of this condition. Since *s* is the summation of the length of the motorcycle and the length of the sensor that it able to cover, *C*, thus the Equation (4) is obtained.

$$(C + length\ of\ motorcycle) = (difference\ in\ velocity\ \times time) \tag{4}$$

Moreover, by comparing the theoretical value and the measure value, the percentage of error can be obtained:

$$error\% = \left[\frac{Theoretical\ value - Measured\ value}{Theoretical\ value}\right] \times 100 \tag{5}$$

III. Results and Discussion

The experimental results for this study will be shown in this section. The results obtained from the experiments that has been conducted are tabulated in table form and graph. Based on the results, the performance of the ultrasonic sensor is analyzed and discussed.

A. Static Vehicle with Moving Object

Figure 10 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 10 (a), at 20kmph ($5.5556ms^{-1}$), the motorcycle is in the SRF04 ultrasonic region at that position is from t = 3s to t = 20s. The distance measured by the sensor starts decreasing at t = 3s. Since the sampling time is 20ms therefore,

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

Thus, 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 = 3.6s and t = 19.2s. Hence,

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

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:

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

As to be compared with the data of Figure 10 (b), at 40kmph ($11.1111ms^{-1}$), the motorcycle is in the SRF04 ultrasonic region at that position is from t = 2s to t = 12s. The distance measured by the sensor starts decreasing at t = 2s. Therefore,

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

The motorcycle is in the region of the sensor for 0.2 seconds. The alarm is turned on in the region between t = 2.3s and t = 11.7s. 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:

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

While the motorcycle moving at 60kmph as depicted in Figure 10 (c), the motorcycle is in the SRF04 ultrasonic region at that position is from t = 3s to t = 12s. The distance measured by the sensor starts decreasing at t = 3s. Therefore,

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

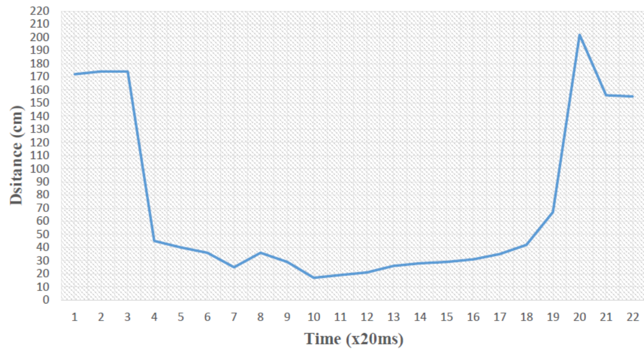
The motorcycle is in the region of the sensor for 0.18 seconds. The alarm is turned on in the region between t = 3.3s and t = 11.7s. Since the sampling time is every 20ms,

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

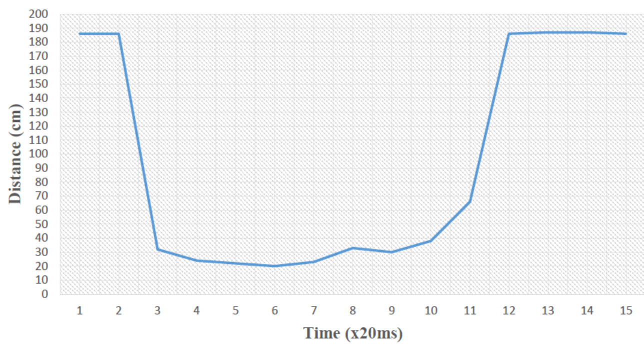
Thus, the alarm is on for 0.168 seconds. Therefore, the difference between the time of that motorcycle in the region of the SRF04 ultrasonic sensor and the region which is set 150cm is:

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

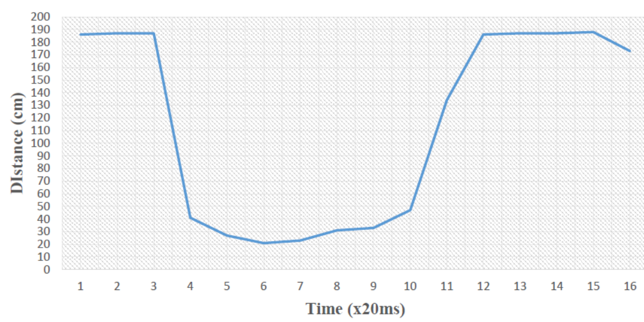
Table 3.1 summarized the errors of the measured values for the static sensor comparing with the theoretical calculation of the Experiment 1.



(a) Motorcycle moving at 20kmph



(b) Motorcycle moving at 40kmph



(c) Motorcycle moving at 60kmph

Figure 10**:** Graph of measured distance over time for motorcycle moving at (a) 20kmph, (b) 40kmph, and (c) 60kmph, of the Experiment 1

Table 1
Calculation summary for Experiment 1

Speed (kmph)	Theoretical value (s)	Measured value (s)	Error (%)
20	0.3254	0.312	4.11
40	0.2029	0.1880	7.34
60	0.1890	0.1680	11.13

B. Moving Vehicle with Moving Object

Figure 11 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. Therefore, the alarm will warn the driver if the distance is less than that length. The sensor which is mounted on the car's body 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 11 (a), the motorcycle is detected in the SRF04 ultrasonic region is from t = 3s to t = 16s. The distance measured by the sensor starts decreasing at t = 3s. Since the sampling time is every 20ms therefore,

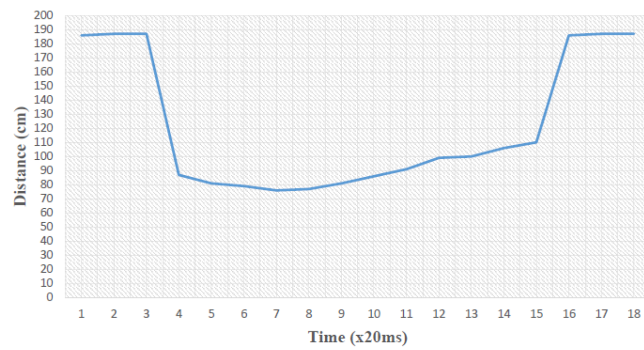
$$(16-3) \times 20ms = 0.26\ seconds.$$

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 = 3.4s and t = 15.6s. Since the sampling time is every 20ms,

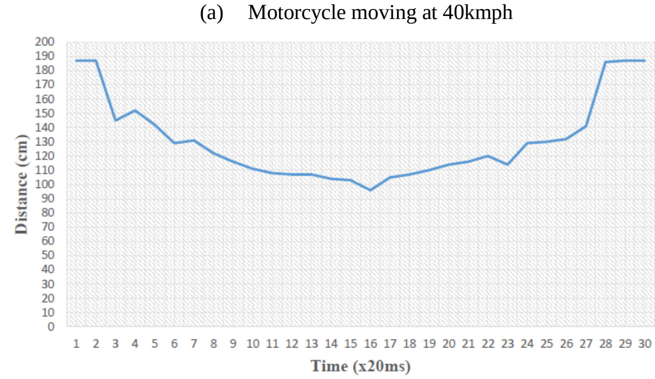
$$(15.6-3.4) \times (20ms) = 0.244\ seconds.$$

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:

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



(a) Motorcycle moving at 40kmph



(b) Motorcycle moving at 70kmph

Figure 11: Graph of measured distance over time for motorcycle moving at (a) 40kmph, and (b) 70kmph, of the Experiment 2.

Table 2 summarized the errors of the measured values for the moving sensor (on the moving car) comparing with the theoretical calculation of the Experiment 2.

Table 2
Calculation summary for experiment 2

Speed: Sensor on car (kmph)	Speed: Motorcycle (kmph)	Theoretical value (s)	Measured value (s)	Error (%)
20	40	0.2817	0.2440	13.38
40	70	0.5449	0.456	16.31

IV. CONCLUSION

The system that will warn the driver about the incoming vehicles in the blind spot area by blinking LED was developed. The system has been implemented and tested with different speed of sensor and approaching vehicle. It were developed by using Arduino microcontroller and ultrasonic sensor. The sensor shows 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 can give a fast notification to the car's driver as the time of the alarm is longer. For further development, 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.

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