Red Light Running

Detect System

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ABSTRACT

Red Light Running (RLR) has been identified as one of the primary contributing factors for motorized vehicle accidents at stop light intersections. In order to understand and ultimately prevent potential victims from these type of accidents, a better understanding of RLR behavior is needed. In this paper, the identified problem statement is to reduce the number of car accidents at stop light intersections by alerting nearby drivers when a car is approaching an incident of red light running. The design of this study is to, first-and-foremost, understand the problem of RLR and identify potential feasible solutions. Once the problem has been identified and understood, we will gather supplies needed to build a first-round prototype that will display a neon sign of light given the car's speed and stopping distance which is read via radar and lidar sensors.

***Keywords**:* Traffic light, red-light running, car accidents, intersection crash, common car collisions

1. INTRODUCTION

Red Light Running (RLR) is defined as a behavior that drivers run through the red light even though the regulations indicate that drivers must stop their vehicles as soon as the traffic light turns red. RLR happens so frequently and fatally at large and complex intersections in the USA that hundreds of people died and tens of thousands of people got injured annually. In 2013, at least 697 people were killed being involved in RLR cases[1]. Such cases greatly raised peoples' attention and many solutions have been proposed to solve the problem. For example, a red light camera and a proper signal timing system. Referencing from [2-5], Two main methods used to reduce red light running cases involve extension of yellow light time change intervals and automated red light enforcement. Studies show that yellow signal timing system reduces red light running. However, these could not be applied to real life because of the high expenses. Therefore, we have developed an alternate solution with a relatively low cost.

Statistics obtained from GES database showed that 88.8% RLR drivers went straight to cross an intersection, while 8.4% RLR drivers turned left[6]. The percentage of RLR drivers who turned right to cross an intersection was lower than that of others', only 2.8%. In this case, we ignored the case involving collision with a Right-Turn(RT) RLR vehicle because the drivers can avoid such a crash on their own judgement simply by looking at vehicles coming straight forward and vehicles on the left.

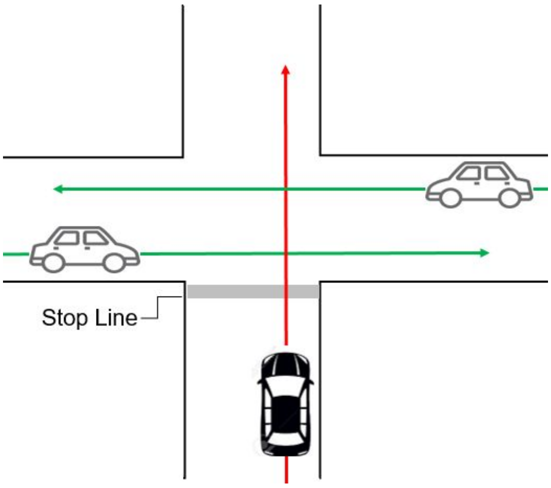

Figure 1. RLR collision type 1, Note : t he red line indicates the approaching path of RLR vehicle; the green line indicates the approaching path of non-RLR vehicle.

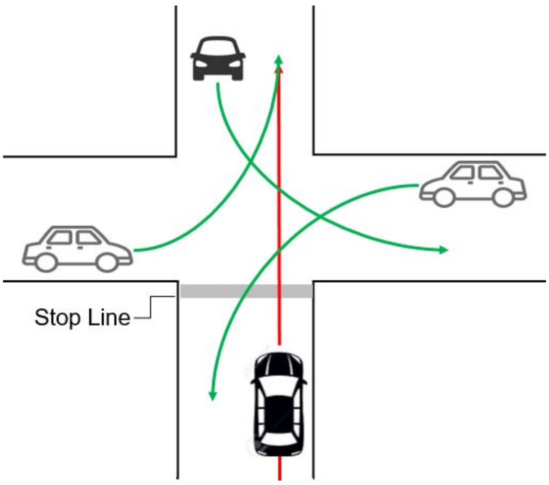

Figure 2. RLR collision type 2, Note : the red line indicates the approaching path of RLR vehicle; the green line indicates the approaching path of non-RLR vehicle.

Figure 1 and Figure 2 are two types of RLR traffic crashes under classified. Figure 1 shows Go-Straight (GS) RLR vehicle colliding with GS non-RLR vehicle and Figure 2 shows GS RLR car colliding with Left-Turn (LT) RLR vehicle.

The RLR system introduced in this research can provide drivers with visualized vehicle stopping distance by marking the predicted stopping line using laser pointer and LED at the intersection. In this way, a warning signal will be given to a RLR vehicle at an intersection so that the RLR driver can top the car beforehand, which helps in reducing the occurrence of a traffic accident.

2. METHODOLOGY

As shown in Figure 3, A lidar sensor and a radar sensor was embedded in the proposed RLR notification system to measure the speed and distance of the vehicle. Using the values obtained, the system calculates the stopping sight distance (SSD) using the formula and visualizes the predicted stopping line on the road through laser pointer and LED[7]. Non-RLR drivers will then be able to make adjustment on their speed accordingly.

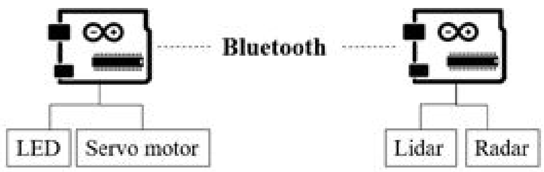

Figure 3. System Diagram

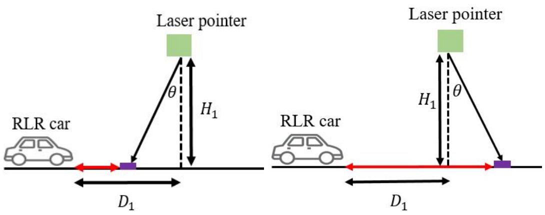

Figure 4. Prototype of RLR system

Figure 4 shows the prototype of a RLR system. Laser pointer and LED will focus according to the angle between the top of the traffic light and the predicted stopping point of the vehicle. Figure 5 shows the formula..

$$\theta = \tan^{-1}\frac{|D_1 - SSD|}{H_1}$$

Figure 5. Angle formula

Comparing to just using a lidar sensor, a combination of two sensors would compensate for the limited coverage of lidar sensor. However, another problem could be raised when it comes to measurements taken in the overlapped area of both sensors. Since, different sensor could generate a different value with a relatively small error (±5 m/s), taking the average value was adopted a possible solution in this case.

2.1. Sensors used in study

A. Lidar Sensor : LIDAR Lite v3

LIDAR Lite v3	
Range	40 m (131ft)
Resolution	+/- 1 cm (0.4 in.)
Accuracy < 5m	± 2.5 cm (1 in.)
Accuracy ≥ 5m	± 10 cm (3.9 in.)
User interface	I2C PWM External trigger

Table 1. Lidar Sensor : LIDAR Lite v3

B. Radar Sensor: HB 100

HB 100	
Range	1-25m
Wide	78°
Interface	USB
Applications	Traffic Monitoring IoT Sensor Drone/Robotics

Table 2. Radar Sensor: HB 100

The reason for using both Lidar sensor and Radar sensor is to reduce blind spot. The Lidar sensor can detect objects on the surface, their size and exact placement, and can detect objects farther than the Radar sensor, but it is difficult to detect objects coming close because of the large blind spot(Figure 6). However, because the Radar sensor can measure a wide range of 78 degrees, the blind spot is small, but the width of the detectable distance is 1 to 25 m, which is smaller than the Lidar sensor(Figure 7). Therefore, using both sensors will not only allow detect of vehicles coming from a distance, but there will be no problem measuring the distance of the closer vehicle.

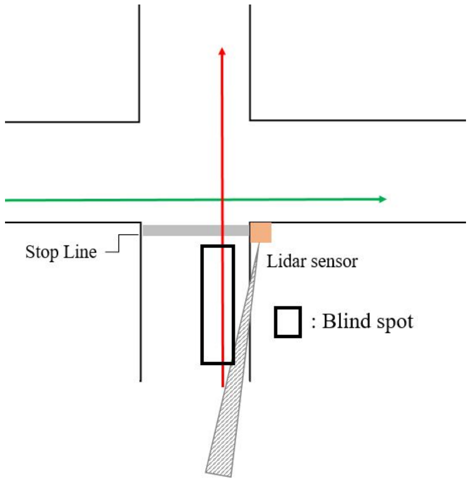

Figure 6. Blind spot of Lidar sensor

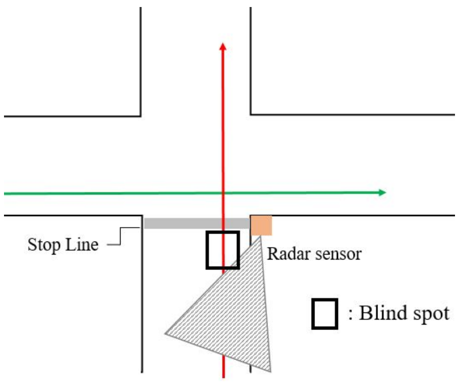

Figure 7. Blind spot of Radar sensor

2.2 Stopping Sight Distance (SSD)

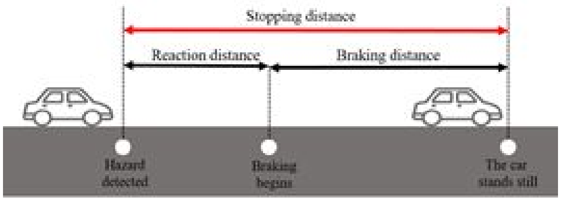

Figure 8. Definition of Stopping Sight Distance

Stopping Sight Distance (SSD) is the distance required for the driver to stop the vehicle after seeing the red light. As shown in Figure 8, SSD is the sum of the reaction distance and braking distance, in which the reaction distance means how far your car travels in the time it takes the driver to react to a hazard and step on the brake. The braking distance means how far your car travels from the time the brakes are applied until it comes to a complete stop. The expression of this formula is shown as follows. [7]

$$SSD = d_{pr} + d_M \quad (1)$$

$$= 0.278V_t + 0.039\frac{V^2}{a} \quad (2)$$

where :

V = design speed, m/s
t = brake reaction time, 2.5sec,
a = deceleration rate, m/s^2

2.3. Algorithm

Algorithm 1 *Get Speed using Lidar*

```
P_t ← previous time
C_t ← current time
Δt ← P_t - C_t
P_d ← previous distance
C_d ← current distance from Lidar Sensor
Δd ← P_d − C_d
if |Δd| <= 2
    V ← 0
    return V
if Δd < 0
    V ← -distance / Δt
else if Δd >= 0
    V ← distance / Δt
return V
```

Algorithm 1 describes the procedure of getting the speed using Lidar. To calculate speed, change of time and distance are required. P_t , C_t , P_d , C_d each denotes previous time, current time, previous distance, and current distance. P_t and P_d are updated with the value of previous C_t and C_d when Algorithm 1 is called. Whenever the distance value is measured by the Lidar sensor, the speed is calculated by the distance and the time.

Algorithm 2 *Get Speed using Radar*

```
P_l ← pulse length, init: 0
for n ← until 2
    P_l ← P_l + pulseIn High from Radar Sensor
    P_l ← P_l + pulseIn Low from Radar Sensor
V ← 0
T ← P_l/2
F ← 1000000/T
V ← F/Doppler Constant
    return V
```

Algorithm 2 describes the procedure of getting speed using Radar. P_l denotes pulse length. By adding the value of pulse from Radar to P_l twice, The team is able to calculate frequency and divide to Doppler Constant.

Algorithm 3 *Calculate SSD*

```
V ← measured speed
B_d ← braking distance
B_d ← V^2 * 0.039/3.4
SSD ← B_d
return SSD
```

Algorithm 3 describes the procedure of calculating the SSD formula. V, B_d each denotes measured speed and braking distance. It is the process of substituting measured values for the aforementioned SSD formula.

Algorithm 4 *Calculate Laser Angle*

```
D ← current distance − SSD
H ← Height
radian ← tan^-1 D/H
degree ← radian * 180/PI
```

Algorithm 4 describes the procedure of calculating angle for turning Laser sensor. D, H each denotes the value of the current distance subtracted by the SSD and height. The radian is calculated by the D and H, and the degree of the Laser sensor can be calculated using the radian.

3. EXPERIMENTS

To test the system, experiments were conducted using a real vehicle. A Toyota was used in these experiments. Road environment was set to a parking lot 20 meters long. The sensor unit was located in front of the vehicle because the range of the lidar sensor was narrower than its specification. The vehicle speed was fixed at 5 mph. When the vehicle started to break from the breaking line, the sensor unit measured the distance to predict the stopping distance until the vehicle actually stopped. Finally we compared the predicted stopping distance with the actual stopping distance.

Experiment 1. Get Stopping Sight Distance

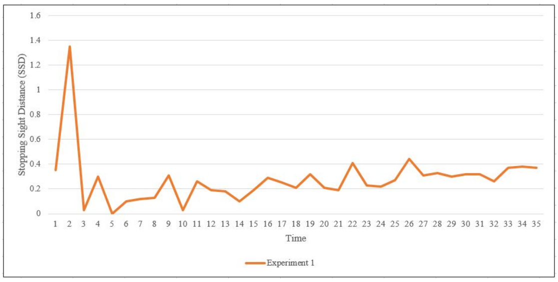

Figure 9. Graph of Stopping sight distance

by (2) we can get a predicted value of the stopping distance. As shown in Figure 8. When the vehicle starts to stop, the stopping distance is 1.35m, at which speed of vehicle is 5 mph. after that, average stopping distance is 0.3m by the vehicle decelerate its speed. The expected SSD at time 2 is 1.6m. This error is caused by wet road and speed of the car is not steady. As the speed of car is reduced, The SSD is reduced. So the average predicted SSD is almost 0.2m.

Experiment 2. Get an angle

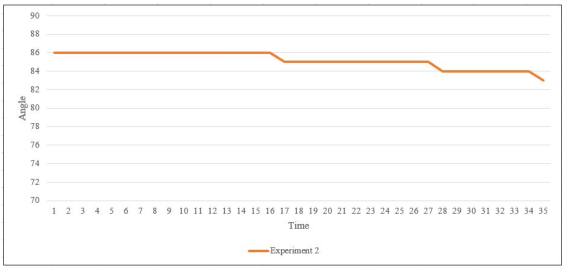

Figure 10. Graph of Angle

To calculate angle of the servo motor which is need for laser beam to show other drivers a line where RLR car's SSD, we need SSD formula and stopping distance from experiment 1. As shown in Figure 10, The angle is gradually decrease when the distance between vehicle and sensor unit is close. This means the system is working. As the car is close to sensor unit, the laser beam moves to show drivers the line.

4. CONCLUSION

In this paper, to fulfill the purpose of solving the red light running problem, determing which vehicle is RLR is necessary. The proposed model alarms non-RLR drivers where the go-straight RLR vehicle coming by laser beam and LED panel. The experiments in this paper were conducted to detect red light running vehicle. Stopping distance is measured by lidar sensor. To compensate lidar sensor, radar sensor is added. It worked well but Lidar is only activated in front of the vehicle. As shown in Figure 9 and Figure 10, Considering wet road and sensor accuracy, Measured SSD has its error, 15%. Research is needed to make these two sensors more used flexible in the future. and the value of angle is reliable but It can't applied to real actuator because of the noise from electric circuit. To stabilize the system, Research about noise canceling circuit is needed.

5. ACKNOWLEDGMENT

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