Bicycle hazard detection application based on optical radar detection module

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Abstract. Most of our current transportations are not suitable for the rapid growth of country and pace of economic activity. In Taiwan, the government provides the alternative solution, namely the "YouBike" public bicycle that could be affordable for most of the residents. However, the accessibility of renting the bike is too convenient, which causes the growth of road users and traffic accidents. In order to record the scene of accidents, it is common for drivers to install a dash camera on any types of transportation for prove of who owns the most responsibility of the accident. Nevertheless, none of the above is able to minimize the probability of traffic accident. Therefore, in order to extend the awareness of the driver, it is necessary to install a distance sensor such as ultrasonic sensor that can indicate the safeness of a distance kept between objects. The project will develop a low-cost LiDAR system with optical sensor for bicyclist to raise awareness of riders by using the reminder alarm to indicate the approaching road users. The substantial of the model and mechanism will be achieved by 3D printer, integration IoT components and sensors to create a self-detect LiDAR system.

1. Introduction

In today's society, transportation has become an essential role that provides accessibility, mobility, and convenience to the residents. With the development of society as well as science and technology, the traffic is getting busier and the number of road users has also increased, which will inevitably affect the traffic. Above all consequences of traffic impact, the bicyclist roadside is the most vulnerable entity among road users, and helmet for bicyclists is not compulsory in Taiwan. When an accident happened to a bicyclist, the bicyclist has a higher risk of injury than the others do.

In the residential area, the speed limit for all vehicles and motorcycles are bound between 40 ~ 60 km/hr. However, the speed of bicyclists is normally around 15 km/hr. In Taiwan, sometimes the roadside is occupied by parked vehicles and it often leads bicyclists to shear stop or turns directions, which can cause traffic accidents to occur. A bicycle does not have a mirror on both sides so bicyclists have to look behind to check and to ensure the distance of oncoming vehicles, which can lead to an accident. The probability of traffic accidents caused by various factors has greatly increased, therefore the current technology has developed optical radar detection devices [9, 10] and unmanned autonomous driving [13] technology to improve the safeness of drivers. For improving the safeness of bicyclists, the project is also focusing on implementing an optical sensor with Arduino main board to develop a low-cost LiDAR system that helps to minimize accidents and alert the user by scanning the surroundings and obtaining the relative distance between road users.

"Time is money", in the modern high-efficiency era, everything is about efficiency and speed, and traffic is no exception. However, busy traffic causes greater losses due to human error, so the question is how to combine the laser distance sensor device with the range scan that will be made into LiDAR (Light Detection and Ranging).

Some of these research questions also consider:

(1) How to use the laser distance sensor device to make the range scanning of the optical radar?
(2) How to design a detection system that checks whether there is an oncoming vehicle from behind?
(3) How to design an alarm function to prompt and assist bicyclists?
(4) How to design the synchronous warning function of the Android mobile APP program and the optical radar module?

2. Literature review and discussion

Safe distance for bicyclist has been a hot topic to determine the minimum distance kept between vehicles and bicyclist. For achieving the goal, there are several advanced technology has been implemented to the topic such as auto emergency brake system, light detection and ranging, ultrasonic sensor and etc that helps to reduce the probability of traffic accident and. To determine the safe distance kept between vehicles and bicycles, we refers to Australian State Government Rule to be the fundamental reference of minimum distance of safety zone that applies to Taiwanese Ministry of Transportation and Communications Regulation.

Auto Emergency Brake System

Most of modern transportations have implemented Auto Emergency Braking System (AEB) as fundamental safety feature. The AEB detects objects from front sensors to measure the object distance and speed which calculates the minimum brake distance based on self-speed. We referred Volvo brand of Collision Warning with Full Auto Brake and Pedestrian Detection (CWAB-PD) model [3], when tow objects drive on the same direction and constant acceleration, the time of collision $t_{collision}$[3] has shown in formula (1).

$$t_{collision} = \begin{cases} -\frac{\tilde{p}_x}{\tilde{v}_x}, & \tilde{v}_x < 0 \; and \; \tilde{a}_x = 0 \\ -\frac{\tilde{v}_x}{\tilde{a}_x} - \frac{\sqrt{\tilde{v}_x{}^2 - 2\tilde{p}_x\tilde{a}_x}}{\tilde{a}_x}, & \tilde{v}_x < 0 \; and \; \tilde{a}_x \neq 0 \\ -\frac{\tilde{v}_x}{\tilde{a}_x} + \frac{\sqrt{\tilde{v}_x{}^2 - 2\tilde{p}_x\tilde{a}_x}}{\tilde{a}_x}, & \tilde{v}_x \geq 0 \text{ and } \tilde{a}_x < 0 \\ \text{undefined}, & \tilde{v}_x \geq 0 \text{ and } \tilde{a}_x \geq 0 \\ \text{undefined}, & \tilde{v}_x{}^2 - 2\,\tilde{p}_x\,\tilde{a}_x < 0 \end{cases} \quad (1)$$

Where $\tilde{p}_x$, $\tilde{v}_x$ and $\tilde{a}_x$ are the distance, speed and acceleration respectively. When the host approaches the stationary target with constant speed, the time of collision is in formula 2.

$$t_{collision} = -\frac{\tilde{p}_x}{\tilde{v}_x} = \frac{\tilde{p}_x}{v_{x,host}}, \quad v_{x,target} = 0 \quad (2)$$

Time of brake formula 3:

$$t_{brake} = -\frac{\tilde{v}_x}{a_{x,host}} \quad (3)$$

Distance of braking formula 4:

$$\tilde{p}_{x,brake} = -\frac{\tilde{a}_{x,host}\, t_{brake}^2}{2} = \frac{\tilde{v}_{x,0}^2}{2\tilde{a}_{x,host}} \quad (4)$$

Time of full stop before collision formula 5:

$$ttc_{brake} = -\frac{\tilde{p}_{x,brake}}{\tilde{v}_{x,0}} \quad (5)$$

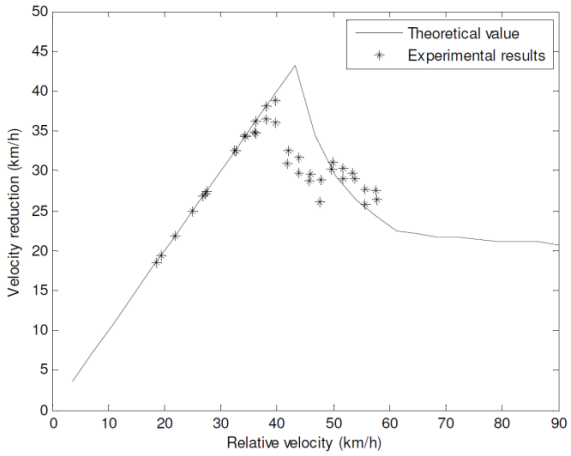

Figure 1. the speed reduction with real life performance [3]

The previous model of Volvo brand vehicle has $-5\ \mathrm{m/s^2}$ [1] maximum acceleration with AEB, the third model of vehicle has $-10\ \mathrm{m/s^2}$ maximum acceleration with CWAB-PD. In reality the AEB has 180ms delay by computation, the theoretical model has shown in figure 1.

Horizontal axis represents the relative speed and the vertical axis represents the speed reduction. After a delay of 180 milliseconds, the speed of about 35 km/hr cannot be stopped in time and the travel distance of the brake will be generated, which means automatic brakes are still dangerous if the speed exceeds 35 km/hr.

Safe Distance for bicyclist

Safe distance applied for bicyclist refers to Australia New South Wales state government regulation that any vehicles passing bicyclist must keep at least 1 meter away and 1.5 meters above if vehicle speed is above 60 km/hr. It ensures the clearance for bicyclists and minimize the risk of collision. Therefore, the safe distance for emergency brake is 35 meters away if the speed is above 60 km/hr.

In Taiwan, the Road traffic safety rules in article 124 under Ministry of Transportation and Communications does not set safe distance between bicyclists specifically. It only shows that driver must keep an approximate distance between vehicles and turning vehicles should yield to directly moving vehicle; vehicle on branch roads should yield.

Due to Taiwanese rule, the safe distance has not shown in the article. We use Australia state government regulation to be the base of safe distance. For safety purpose, the vehicle driving on the road should keep at least 30 meters away behind the bicyclist. That gives clearance to approaching vehicle when bicyclist is changing lane.

External detection Technology

External sensors have been developed for decades, and most sensors have improve precision on the measurement. On the market, there are several sensors have been well known and commonly use which are Infrared radar, ultrasonic wave radar, millimeter wave radar, light detection and ranging and camera. Comparing above sensors, LiDAR sensor are capable of adapting long ranging.

Table1：Comparison of External sensors

	Effective distance	Effective range	Directivity	Night environment
Inferred Light			V	V
Ultrasonic				V
Microwave	V	V		V
Millimeter Wave	V	V	V	V
Camera	V			

Light Detection Theorem

The optical sensor used in this project is LiDAR Lite v3 HP, it measures the distance between the source of the light and reflected surface by calculating the Time of Flight traveling. The distance calculation is shown on formula (6).

d= distance
c= speed of light
t= time of flight

$$\mathrm{d} = \frac{\mathrm{c} \cdot \mathrm{t}}{2} \tag{6}$$

From formula (6), the given distance is measured by calculating the TOF. Considering the

reflection on the surface of the object which causes biases, the reflection angle of the light is constrained to the angle that limits the effectiveness of the light received. Figure 2 has shown the reflection biases.

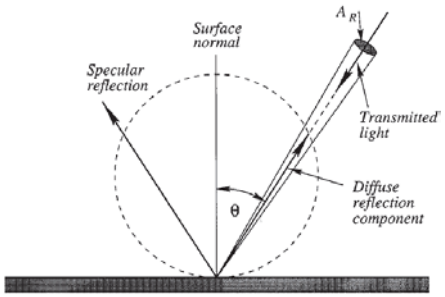

Figure 2. TOF reflection on surface [1]

3. Research methods and steps

The LiDAR module will integrate all IoT and 3D print components to form a scanning function of 40 meters radius range. The scanning function rotates 360 degrees on the horizontal line to show scanned objects on the radar map. The wiring diagram and flowchart explains further details on data processing and each of the functionality of the IoT components. The scan result will be shown on mobile phone and it will immediately give the user an alert if the distance kept is not safe.

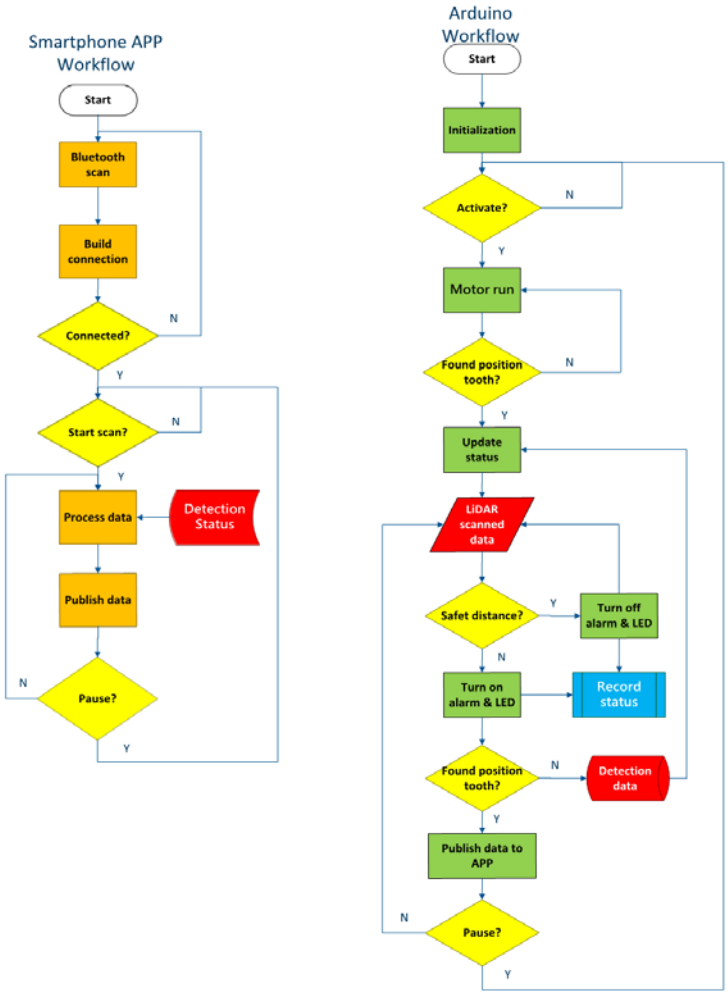

Figure 3. Workflow of Arduino UNO and smartphone APP[8]

Firstly, Arduino UNO starts real-time computing to obtain raw distance data from optical sensor and transmits the data after one full scan of rotation to smartphone via Bluetooth which has installed APP already. The smartphone shares the workload of real-time computational device to process the raw data. The workflow has shown in figure 4.

By integrating the external sensor device with Arduino UNO, the data can be determined with the rotation angle in full scan data. The mobile phone APP provides a visual graphic to indicate the scanned distance in four directions. If any object is within 1.5 meters on the left, right, and front side and 30 meters on the back side, it will indicate a sign of danger and raise the alarm to warn the user that a safe distance is not to be kept.

By integrating the optical sensor with Arduino UNO, the data can be determined the rotation angle in a full scan data. The APP provides visual graphic to indicate the scanned distance in four directions. If any object within 1.5 meters on left, right and front side and 30 meters on back side, it will indicate sign of danger and raise the alarm to warn the user that the safe distance is not be kept

The wiring diagram of the low-cost LiDAR system shows that Arduino UNO communicates with LiDAR Lite v3 HP, Bluetooth, counter sensor and DC motor to perform full scan data from the environment. The smartphone receives the data through Bluetooth after each full scan and starts process the data which makes the data readable for the APP user. All the safety functions are integrated into the APP to ensure the APP user keep a safe distance.

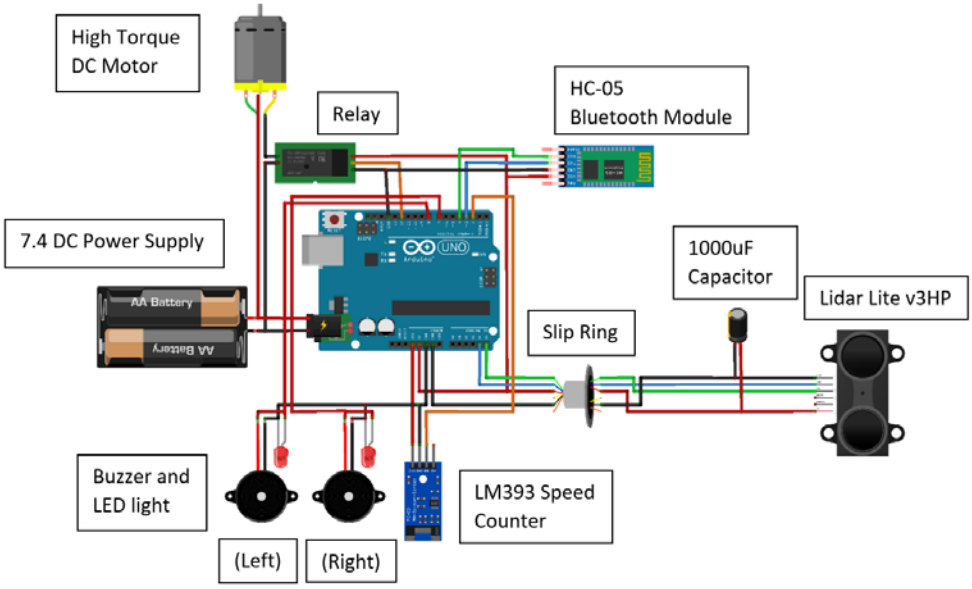

Figure 4. Wiring diagram of the system

When the distance and angle data are successfully uploaded to the mobile phone APP, it starts to analyze whether the user maintains a safe shoulder distance. The general road hours in the urban area are limited to 40 kilometers per hour, but considering the speeding problem, based on this point Setting, if the shoulder of other road users is within 1.5 meters (inclusive) and the distance of the following vehicle is within 30 meters (inclusive), the warning light will start to flash and the siren will sound, and the warning and siren functions will be synchronized on the mobile APP. In order to remind the cyclist, especially when the bicycle changes lanes, it can remind the cyclist to check the movements of the left and right and rear vehicles.

4. Conclusion and Future work

The danger detection device connection to mobile device can display the current distance to the objects by showing four directions on the screen and conditional signs are given based on the relative

distance. The conditional signs shown on the relative direction informs APP users the distance kept in between objects is not in safe zone and raises alarm to alert APP users.

On the hardware part, the customized encoder ring on danger detection device assembling with counter sensor computes the current rotating angle via Arduino UNO processor and obtain relative measured distance by Lidar 3HP optical sensor. The two arguments given by two sensors are projected into two-dimensional coordinate system that visualize all scanned objects on the two-dimensional map. In the result of the scanning phase, distance measuring is interfered by translucent material and metal material that highly increase distance measurement error caused by optical diffusion and reflection. Furthermore, the darker color on the measured object also reduces sensitivity of measurement by light absorption. To overcome measurement error, danger detect device will adapt multiple sensors such as depth camera and ultrasonic sensor that detect external environment by different approach. The consistency of distance measurement and auxiliary sensors heavily stabilizes range detection and accurately give warning signs to the users.

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