Traffic Sensing Bicycle Light

ECE 445 Design Document

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1 Introduction

1.1 Objective

Despite the stronger awareness and appearance of bike-only lanes, there were still about 840 bicyclists killed in motor vehicle accidents in the U.S. in 2016, which was 2.2 percent of total motor vehicle traffic fatalities. Moreover, about 58% of bicyclists fatalities did not occur at intersection locations, which 28% more than accidents occurred at intersections [1]. Therefore, it will be extremely helpful to have a device at the back of the bike to alarm both bicyclists and drivers and prevent potential accidents.

Our intention is to make a device that is designed to sense traffic coming from behind and operate three different types of modes to alarm car drivers based on the relative distance and speed of approaching the vehicle in order to reduce bicycle accidents involved with cars.

1.2 Background

There are several similar devices as our project in the market, but they serve different or simpler functionalities. Some devices only flash a red light when it detects the bicyclist hits the brake and some will alert the bicyclist through some compatible Edge bike computers. However, those alerts are not that useful and effective as ours because our project provides three different modes for different situations.

Installing such a traffic sensing bicycle light at the back of the bicycle can effectively help bicyclists to be aware of potential traffic dangerous approaching from behind and alarm car divers by using three different alarm types for different situations. As the rear distance becomes smaller and relative speed increases, the alarm type will changes from a flashing red light to high-intensity white strobe light, and eventually an audible alarm, which increases the effectiveness of the alarm.

Our device can also be connected to a phone via Bluetooth to adjust parameters for range and relative speed setting for different modes.

1.3 High-Level Requirements

- The device has to distinguish between vehicles coming from behind and cars parking beside, passing by and passing in the opposite direction, and it also has to distinguish between a car behind and a cyclist or pedestrian.
- The device has to have 4 modes of operation to alarm approaching drivers.(check *Table 1* for specific information for each mode).
- The cost of the device is limited to 150$

2 Design

The light requires five sections for a successful operation: a power supply, a control unit, a sensor unit, a processing unit, and a camera unit. The power supply unit, which contains 27V of power supply along with Voltage Regulator for different modules of the device, makes sure the device can run at least 5-6 hours a day. The control unit contains a microcontroller (Atmega328p), which has 32KB flash memory and is able to handle the incoming data continuously from the sensor module. And then the control unit would determine which output device to activate. Lastly, the user can change the parameters of distance, and velocity threshold for the sensors on their mobile device that communicates with the control unit via Bluetooth.

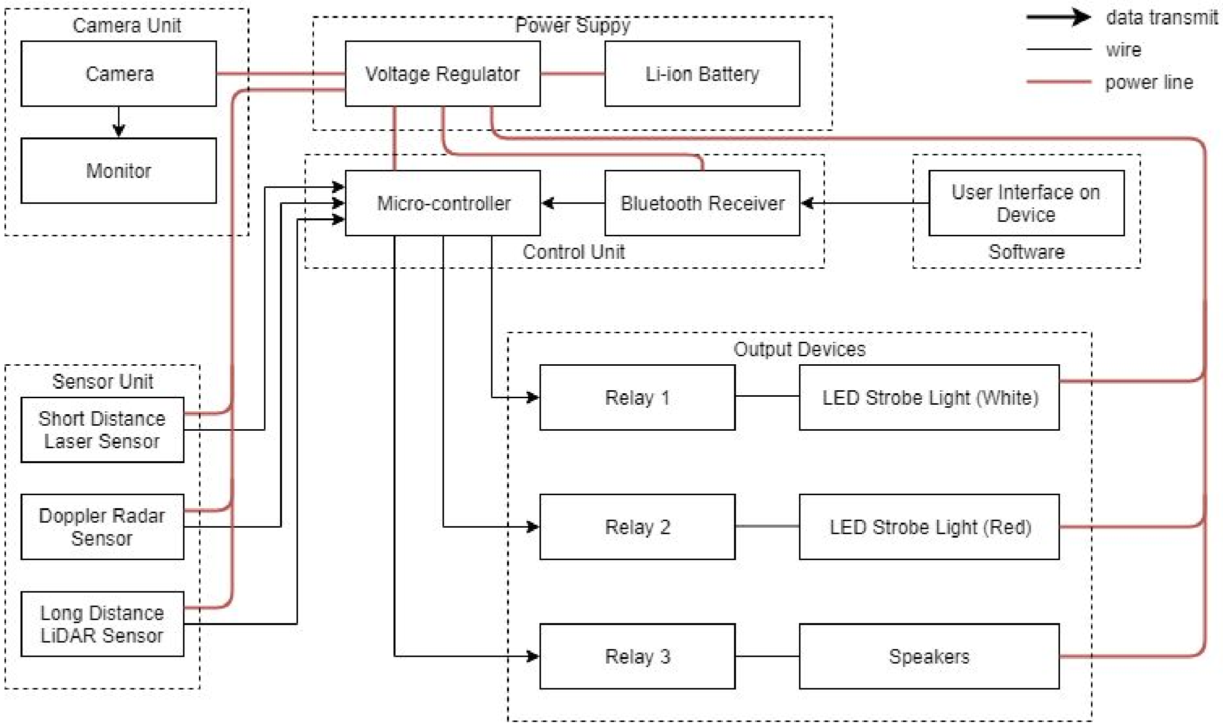

Figure 1. Block Diagram

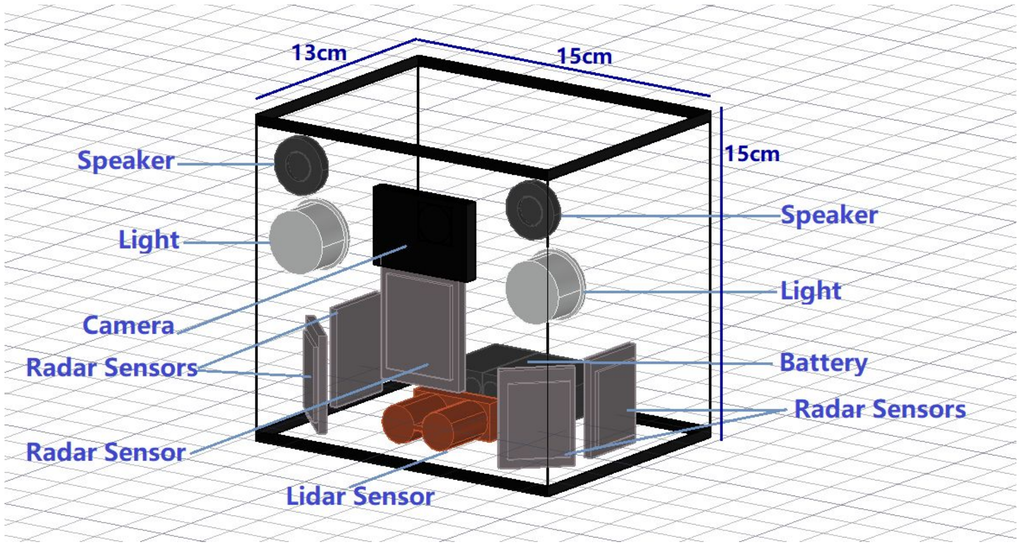

Figure 2. Physical Design

2.1 Sensor Module

The sensor module is the input of the device. The sensors we are going to use one Garmin Lidar sensor (SEN-14032) that place directly on the back for rear crash detection and two Doppler radar sensors (SEN0192) that are placed on the left and the right for side crash detection. And also, three short range lidars (SEN0245) are placed on the rear and both left and right sides for close distance detection. The Garmin Lidar with its 2 to 40m detection range is responsible for rear crash detection. And then the Radar Sensors that are placed on the left and right are responsible for side crash detection by measuring the perpendicular-to-the-antenna distance change over a specific time and the current distance. And the overtaking from behind by the vehicle would not falsely trigger any modes, because of perpendicular-to-the-antenna distance would not have a significant change in seconds. Therefore, it would not falsely trigger the horn mode. The same goes to the parked car and pedestrian. And the short range laser sensor is to have a warning sound for the approaching car at low velocity. The legal distance between a vehicle and a bicycle is about 1m. If the car is closer than 1.5m, warning sound would be played periodically.

Requirements	Verifications
1. The Garmin Lidar sensor (SEN-14032) can correctly collect velocity and distance data 2. The Radar Sensor (SEN0192) can detect the distance that is perpendicular to the parallel surface of the antenna.	1. A. Connect the sensor to the Control Module and use a testing program that contains the distance threshold of 3m and approaching velocity of 0.5m/s. And connect the output to a simple LED

3. The close distance laser sensor can detect close distance object	B. Run the program to check if data from the input exceeds thresholds. If both input data is higher than thresholds, the LED turns on 2. 3. A. Connect the sensor to the Control Module and use a testing program that contains the distance threshold of 1.5m. And connect the output to a simple LED B. Run the program to check if data from the input exceeds thresholds. If the distance between the testing object and the sensor is smaller than 1.5m the LED is on.

2.2 Control

A control unit that is able to take the data from the sensors as input and determine which output device should be triggered according to the data collected.

Distance of 33m (109ft) or closer (20m,40m)	Velocity of 17.88 m/s (40MPH) or faster (15m/s, 20m/s)	Potential Rear Crash detected, activating flashing white strobe light
Distance of 19.2m (63ft) or closer (10m,20m)	Velocity of 13.41 m/s (30MPH) or faster (10m/s, 15m/s)	Potential Rear Crash detected, activating flashing red strobe light
Distance of 8.23m (27ft) or closer (2m, 10m)	Velocity of 8.94 m/s (20MPH) or faster (5m/s,10m/s)	Potential Rear Crash detected, Triggering horn for final warning
Distance of 8.23m (27ft) or closer	Velocity of 8.94 m/s (20MPH) or faster	Potential Left/Right side crash detected, triggering horn for final warning
Distance of 1.5m (For left or right side ultrasonic sensor)	N/A	Close distance detected, warning sound trigger with a delay of 2s

Table 1: An example of a trimmable parameter and the range calculated according to NACTO [3], a national traffic organization

2.2.1 Microcontroller

Microcontroller,Atmega644a with 64KB flash memory, is chosen to handle data management collected from the sensors input and determine which mode or device should be activated accordingly. And it is also able to receive user's input by via UART by Bluetooth for the triggering parameters on the Garmin Lidar sensor. The microcontroller is programmed through a JTAG interface. In order to use a mobile device to input the parameters the user want, addition Bluetooth transceiver HC-05, which has a detecting range of 10m, is needed to handle the wireless data transmission.

Requirements	Verifications
1. Can both receive and transmit over UART at a speed at least 120kbps 2. Can receive the input data from all three sensors (SEN-14032, SEN0192, SEN0245) 3. Can give out signals to activate output devices	1. A. Use a test program that output the variable that stores the input received from the UART to the console B. Type in a set of data of parameters from the device and send it to the microcontroller C. Check the output on the console see if it matches to what was input from the mobile device 2. A. Use a test program that outputs the threshold value to the console if the data collected from the sensor reaches the threshold B. Use a testing object on the sensors to reach the threshold for each sensor C. Check if the test program correctly output the correspondent values 3. A. Use a test program that sends a active low signal to the pins where the output devices such as the strobe LED and speaker are connected. B. Check if the corresponding activated device is on

2.3 Output

Two 12V relays would be used between the two output LED strobe lights and the control unit. A 5V relay would be used between the output speakers and the control unit. The light and speakers would be turned on only when the control unit sends a signal to close the circuit.

2.3.1 LED Strobe Lights

Requirement	Verification
1. Can blinks when relay is active 2. Provide bright enough light that the driver is able to see	1. Connect the LED lights in series with the relays 2. Operate the relay in a desire way, check if the LED blinks as it is set up 3. Turn on the LED light and place it near the road in day and at night 4. Check if the LED light is able to be seen

2.3.2 Speakers

Requirement	Verification
1. Can play sound when relay is active 2. Provide loud enough that the driver is able to hear	1. Connect the speakers in series with the relays 2. Operate the relay in a desire way, check if the speakers operate as setup 3. Play the sound and place it around a car 4. Check if the drive is able to hear the sound

2.4 Software

The control unit will be accessed by phones via Bluetooth. Parameters for range and relative speed for different modes of operation can be changed by a user interface.

Requirement	Verification
1. Can use bluetooth connected device to modify the parameters in microcontroller	1. Use bluetooth from cell phone to connect 2. Check if it could change the parameter

2.5 Power Supply

The power supply provides the circuit with maximum 27 volts powered by three 9 volts NiMH batteries. It supplies the control unit, the sensor unit, the output devices and the camera, with approximately 3100mA in total. The camera, speakers ,and LED lights take majority of the current.

2.5.1 NiMH Battery

Three 9 volt 2000mAh NiMH rechargeable batteries would be the source to continuously power the circuit.

Requirement	Verification
1. Provide more than 3100mA current	1. Connect three batteries in series in a test circuit 2. Measure the output current using a oscilloscope

2.5.2 Voltage Regulator

A 12 volts and a 5 volts voltage regulators would be used to maintain constant a voltage from the batteries source. The BA50DD0T-ND would be used for the 5V voltage regulator. The 576-2223-ND would be used for the 12V voltage regulator.

Requirement	Verification
1. Maintain a constant 5 volt voltage level 2. Maintain a constant 12 volt voltage level 3. Can operate a currents within 0-2000mA	1. Connect the voltage regulator in a test circuit 2. Measure the output voltage using an oscilloscope 3. Choose proper load connected to the circuit 4. Measure the output current using an oscilloscope

3 Cost

The fixed development costs are estimated to be $20/hour, 12 hours/weeks for three people. It approximately takes 11 weeks to be done.

$$3 \cdot \frac{\$20}{hr} \cdot \frac{12hr}{wk} \cdot 12wk = \$8640$$

Part	Cost
9 volt 2000mAh NiMH rechargeable battery *3 (Amazon; Energizer)	$26.55
5 volt voltage regulator (Digikey;	$3.01
12 volt voltage regulator (Digikey;	$4.26
Microcontroller (Digikey; ATMEGA644A-PU-ND)	$4.38
Bluetooth receiver (Amazon; HC-05)	$11.11
Short range laser sensor *3 (Digikey; 1738-1397-ND)	$42.66
Doppler radar sensor *2 (Digikey; 1738-1064-ND)	$33.74
Long range LiDAR sensor (Amazon; LIDAR-Lite v3)	$129.99
5 volt relay (Digikey; 255-5499-ND)	$4.01
12 volt relay *2 (Digikey; TX2-12V-TH-ND)	$8.02
LED strobe light *2 (Amazon; Hontiey)	$6.49
Speakers *2 (Digikey; 102-3841-ND)	$7.40
Total	$281.62

4 Schedule

Week	Assignment
02/18/2019	Complete design document with further details; Order parts
02/25/2019	PCB design for the whole circuit
03/04/2019	Power supply test
03/11/2019	Sensor test
03/18/2019	Sensor test
03/25/2019	Output devices test
04/01/2019	Bluetooth test
04/08/2019	Prepare mock demo
04/15/2019	Mock demo; Prepare demonstration
04/22/2019	Prepare presentation; Start final report
04/29/2019	Complete final report

5 Ethics and Safety

There are several safety concerns we have for our project. Since the device will be connected to a standard flashing red light, high-intensity white strobe light, and a horn, we at first concerned about the power safety. Fortunately, it turns out approximately 27 volts would be needed for the project, which would be relatively safe to human. Another concern would be that if the high-intensity white strobe light is too bright, it would potentially cause drivers behind dizzy or even unable to see. Therefore, further testing on the strobe lights will be conducted to determine the frequency of the lighting pattern.

Since the device is attached to a bicycle that would be often driven outside and experience very rainy or sunny weather, which could cause a short circuit and other potential safety problems. In that case, a waterproof case with heat-sink would be used for the device.

For power, since we have a Li-ion battery, situations like overcharge may occur, which can cause damage to other modules.

Our project aligns with the IEEE Code of Ethics because our device itself is safe and will not do any damage to others. Moreover, our device is supposed to alarm both bicyclists and car drivers and prevent potential dangers, which results in decreasing the bicycle accident involved with cars. Therefore, our project will definitely " hold paramount the safety, health, and welfare of the public" and "disclose promptly factors that might endanger the public or the environment"[2].

References:

[1] NHTSA's National Center for Statistics and Analysis, "Bicyclists and Other Cyclists", 2016. [Online]. Available: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812507

[2] Ieee.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 29- Feb- 2016].

[3]Nacto.org. (2019). [online] Available at: https://nacto.org/docs/usdg/vehicle_stopping_distance_and_time_upenn.pdf [Accessed 8 Feb. 2019].

[4]"Road Safety Factsheet", Rospa.com, 2017. [Online]. Available: https://www.rospa.com/rospaweb/docs/advice-services/road-safety/cyclists/cycling-accidents-factsheet.pdf. [Accessed: 08- Feb- 2019].