Traffic Sensing Bicycle Light

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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 supports three modes of operation:

Mode	Rear Distance	Relative Speed	Alarm type
Normal	> D1 feet	< S1 mph	Standard flashing red
Warning	<= D1 feet	>= S1 mph	Add high-intensity white strobe light
Danger	<= D2 feet	>= S2 mph	Add audible alarm

- The light 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.

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.

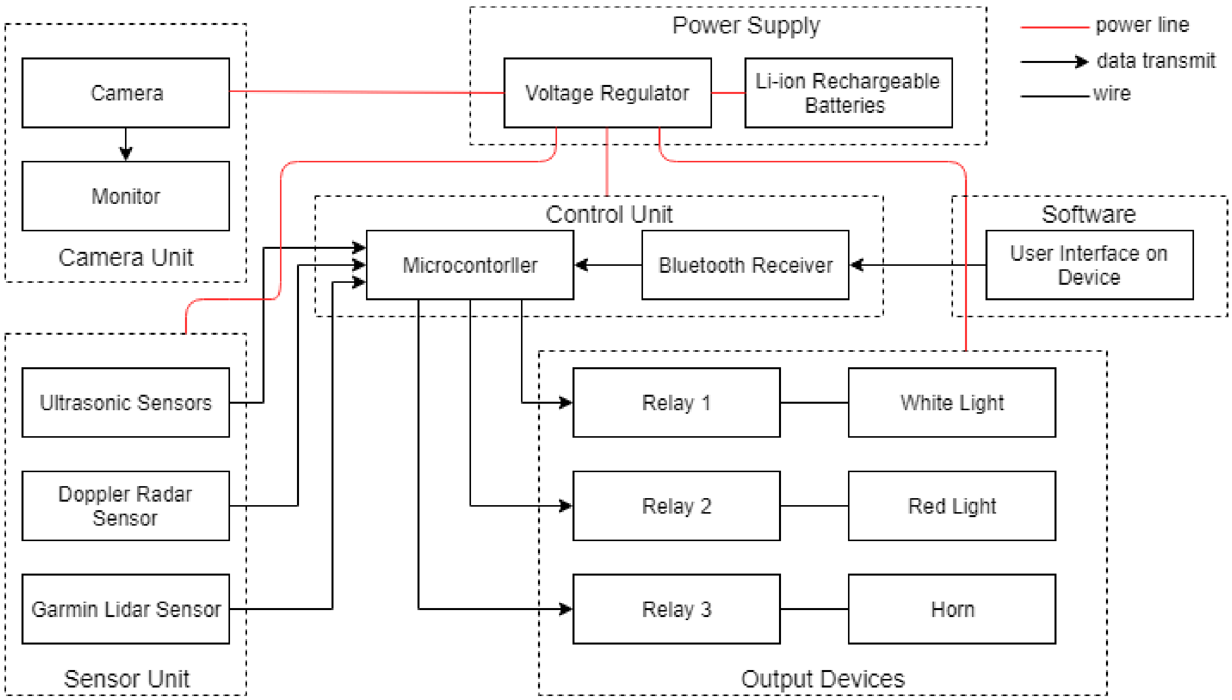

Figure 1. Block Diagram

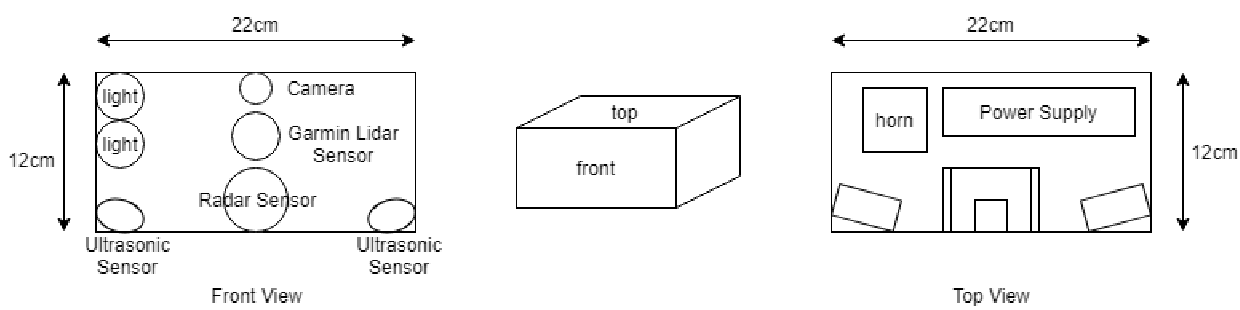

Figure 2. Physical Design

2.1 Sensor Module

Data will be collected using the ultrasonic sensor, Doppler sensor, and Garmin sensor and then sent to the control unit. Each sensor serves different purposes. Garmin Lidar sensor (SEN-14032) with its maximum detecting range of 40 meters is able to detect the approaching object's velocity as well. In this case, we will only need the close and mid-range (2-16m) radar sensor. And for close range and detecting cars that are just passing by the bicycle, we will use ultrasonic sensors (SEN-13959) that are placed on each side of a radar sensor (SEN0192) on the middle, shown on the physical design above. This can prevent false alarm being triggered by cars that are passing by. A final warning would only be triggered when all three of the sensors have detected the approaching vehicle. Two separate ultrasonic sensors would be placed on the left and right side of the device to detect the vehicle that is crashing from the side. With passerby vehicle detected from rear main sensors, the microcontroller will disable the side sensor or ignore the trigger data.

Requirement: All three kinds of sensors should be able to sense the fast approaching objects and collect the related velocity and distance data at a frequency of 10Hz or more.

2.2 Control Module

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	Velocity of 17.88 m/s (40MPH) or faster	Activating flashing white strobe light
Distance of 19.2m (63ft) or closer	Velocity of 13.41 m/s (30MPH) or faster	Activating flashing red strobe light
Distance of 8.23m (27ft) or closer	Velocity of 8.94 m/s (20MPH) or faster	Triggering horn for final warning
Distance of 1.5m (For left or right side ultrasonic sensor)	Velocity of 4.3m/s or faster	Triggering horn for final warning

Table 1: An example of a trimmable parameter according to NACTO [3].

2.2.1 Microcontroller

Microcontroller (Atmega328p) 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.

Requirement 1: The microcontroller must be able to communicate via UART with HC-05 transceiver in a 3Mbs data rate.
Requirement 2: The microcontroller must be able to receive data from sensors.
Requirement 3: The microcontroller must be able to send out signals to output unit regarding the data received.

2.3 Output Module

12V Relays would be used between the output devices (2 12V 10W LEDs) and the horn (PH-143Q). The light and horn would only be turned on when the control unit sends a signal to the relay to close the circuit. A regulator would be used in the horn to provide the required voltage which is 8.9V (+/-5%). The voltage would be powered by the power module via the regulator.

Requirement: When the relays receive the active low signals, the output devices turn on.

2.4 Software module:

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: User can use Bluetooth connected device to modify the parameters in the microcontroller.

2.5 Power

A power supply would be required to keep all modules working and communicating. Power from the rechargeable battery would regulate about 27 Volts.

2.5.1 Li-ion Battery

Three rechargeable 9 Volt lithium-ion battery would act as the voltage source to continuously power the circuit.
Requirement: The battery must be able to supply the circuit for at least 6 hours.

2.5.2 Voltage Regulator

The voltage regulator acts as a buck converter, converting input voltage to a lower voltage required by the microcontroller, and the other parts of the circuit.

Requirement: The voltage regulator must be able to continuously output stable +12V.

2.6 Camera (Separate System)

A camera would be placed right next to the sensors to record the traffic and sent to a monitor at the font in real time. A modified GoPro would be used to live stream rear feed to a portable display that is attached to the front bar of a bicycle. Additional power would be needed for the latency of this system.

Requirement: Live stream feed on a portable screen for 5 to 6 hours in room temperature.

2.7 Risk Analysis

Sensors performance and control logic would have a decisive role in a successful device. Majority of the device functions relies on the feedback from the sensors. And all the sensors can work properly in extreme temperature (-20 degree Celsius to 60 degree Celsius). However, a wet working environment may have effects on the device. So if the user rides the bike with the device on a rainy day, the performance would be poor compared to that in a dry environment. The raindrops would damage the sensors if not protected by additional covers. Performance in a moist environment would need to be tested. And additional waterproof materials can add to protect the sensors to build a more robust device.

Another key part is the internal logic for the microcontroller. In order to build a device that can work in a dynamic environment, the internal logic on determining potential crashes from other angles other than the rear is necessary. And the most common crashing incidents happen when the vehicle tries to make a turn with poor judgment [4]. Therefore, additional sensors on the side that work accordingly with other sensors are essential. And to distinguish a overtaking car passing by the cyclist or a potential crash on the side, we have the ultrasonic sensor on the side would monitor the distance and the velocity of the moving objects. It activates the horn in the case of a potential crash on the side if the passing by scenario is negative and the velocity and distance triggers the side sensor. We can have the microcontroller not taking any data from the side sensor if passing by scenario is detected. Velocity would only take into account if the direction is orthogonal to the frame of the sensor, meaning an approaching object to the cyclist.

3 Ethics & 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

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