Vehicle Early Warning System

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A Cyclist-Focused Approach to Road Safety

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Abstract

According to the U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA), a total of 36,560 people were killed in traffic accidents in the United States in 2018. NHTSA claims the number of traffic fatalities has decreased over the last 40 years as a result of a combination of factors such as efforts to combat drunk driving, improved vehicle-safety features and increased seat belt use. Although traffic fatalities have decreased among virtually all categories in the study (e.g. traffic fatalities involving large vehicles, motorcyclists, alcohol-impaired driving, etc.), traffic fatalities involving pedestrians and cyclists show an opposite trend.

The NHTSA reports pedal cyclist deaths comprised 2.3% of all traffic deaths in the United States in 2018 and approximately 75% of those deaths occurred in urban areas. Furthermore, it is estimated that 47% of all pedal cyclist deaths occurred during nighttime hours. Large cities often lack the infrastructure conducive to the safe operation of a bicycle: Narrow and/or unprotected bike lanes have been a common and ongoing complaint from cyclists and city governments have made little progress in addressing these concerns. Since it's often not practical to increase the size of bike lanes or install protected bike lanes throughout urban areas and as cycling-and especially electric bicycles-become more popular as a viable means of transportation, exploring alternative methods to keep cyclists safe will become increasingly important.

This paper was generated to illustrate an early warning system called VEWS, pronounced 'views', that will assist in mitigating traffic deaths involving cyclists. VEWS recognizes the limitations of changing long established infrastructure to accommodate cyclists and provides a practical and cost-effective alternative to bicycle safety that targets the intersection of deaths that occur both at night and within urban areas.

How It's Different

Traditional safety equipment such as reflective vests, bicycle safety lights and other reflective material all have one thing in common: They are vehicle focused. In other words, these safety products rely on the vehicle driver to be the one that observes the cyclist while the cyclist must hope and pray she has been observed by the driver. In this situation, it's clear the opportunity to react is stripped from the cyclist because the cyclist cannot control the attention of the driver. However, VEWS allows the cyclist to play an active role in their own safety because it’s cyclist-focused: VEWS allows cyclists to be the observer and this reversal of the observer role gives the cyclist the opportunity to react to any potential danger. These cyclist-focused safety measures will become more prominent as cycling as a form of transportation increases, as well as the inevitable increase in vehicles that are becoming harder and harder for cyclists to detect through sound alone (e.g. electric vehicles).

How It Works

VEWs is an electronic device with a light emitting diode (LED) light strip that is affixed to the crossbar of the bicycle. Since VEWs is small and flexible, it can also be affixed to the handlebars, which would allow for even better viewing for the cyclist. The LED strip turns red when a vehicle gets within a 400cm distance and these flashing lights warn the cyclist that potential danger is approaching.

The Details

The device uses the following components: One Arduino Uno R3 microprocessor, one 330 Ohm resistor, one HC-SR04 ultrasonic sensor, one 5-volt power source and one individually addressable RGB LED strip comprising thirty individual LEDs.

The ultrasonic sensor comprises two transducers; one sends a signal in the direction that it’s pointed and the other receives the signal reflected from an object within a 400cm range, which is the maximum effective range of the ultrasonic sensor. When a 10 microsecond 5-volt pulse is applied to the trigger pin, the sensor transmits eight 40kHz ultrasonic waves in a unique pattern toward the direction the transmitter is pointing. The ultrasonic sensor is affixed to the bicycle in such a way that the ultrasonic waves propagate 135 degrees from the direction the cyclist is traveling. Immediately after the signal is sent, the echo pin is set to high and generates an echo pulse that lasts no longer than 38 milliseconds. If the receiver does not receive a signal within 38 milliseconds after the echo pulse was initiated, then this indicates no objects were detected within the 400cm range, or in other words, no signal bounced back to the receiver. However, if the ultrasonic sensor receiver receives a signal that is bounced back, indicating the presence of an object, then the echo pin will be set to low and generating an echo pulse duration that will be less than 38 milliseconds (the echo pulse will be a value between 150 microseconds to 25 milliseconds long. The width of the echo pulse will be used to determine the distance between the sensor and the object using the well-known equation distance = speed x time.

The Issues

One disadvantage of using the HC-SR04 ultrasonic sensor has to do with the range: Theoretically, the vehicle would have to be within approximately 400cm of the cyclist for the sensor to notify the presence of the vehicle. However, during the testing phase, it was found that the sensor would not work consistently for objects within a 200-400cm range and this result was found using multiple HC-SR04 ultrasonic sensors. This means that the sensor would work consistently for objects within 200cm, which seems far beyond the comfort zone of most cyclists. It is reasonable to conclude that this result could have been mitigated by using other ultrasonic sensors with higher quality. Higher quality sensors were found within $200 - $300 range and could be good candidates for future versions of VEWs.

Other sensors were initially tried such as the RCWL-0516 proximity sensor. This proximity sensor has an operating voltage between 4-28 volts and transmits a 3.18 GHz frequency at a maximum effective range of 7 meters. The sensor exploits the properties of the Doppler Effect by transmitting a microwave signal at a specified frequency: Objects approaching the sensor will reflect the signal back to the sensor at a higher frequency and objects moving away from the sensor will reflect the signal back at a lower frequency. The difference between the microwave frequency that is transmitted and the wave that is received is what notifies the sensor of an object’s presence. It was later discovered that this method of object detection has some disadvantages; The most important disadvantage is the microwave transmits in all directions. This resulted in the sensor constantly detecting the presence of the cyclists, who is always moving. The problem is avoided with the HC-SR04 ultrasonic sensor because the wave travels in a specific direction, which is the direction the sensor is pointed.

The Conclusion

VEWS is the best solution because it allows the cyclist to play an active role in ensuring their own safety as opposed to relying on drivers observing cyclists. This solution will give cyclists ample time to react to potential danger from approaching vehicles. Clearly this poorly constructed prototype is not good and has many issues but the concept of a cyclist-focused approach to bicycle safety will become a necessity as vehicles evolve, modes of transportation evolve and as cities themselves evolve to become more sustainable for future inhabitants. The VEWS prototype is simply a prototype intended to illustrate the need for cyclist-focused devices and subsequent versions of the project will account for and mitigate issues previously discussed.

Appendix (Source Code)

BicycleWarningSystem

```
/**The following code represents the functionality for
 * a Vehicle Early Warning System called VEWS. The hardware
 * is affixed to a bicycle at an appropriate angle to allow
 * for the detection of objects/vehicles within a 400cm range.

 * Author: Condie Howell
 * Class: Computer Architecture
 * Last Updated: 18 Nov 2020 */
#include <FastLED.h>
//*****************************SECTION 1*********************************
/*LED STRIP INFORMATION*/
#define LED_PIN 7
#define NUM_LEDS 30
CRGB leds[NUM_LEDS];
/*define pins for HC-SR04 ultrasonic sensor*/
#define trigPin 10
#define echoPin 13
/*Define functions for lighting LED strip*/
void light_strip_green();
void light_strip_red();
/*Variables for subsequent use in the distance equation*/
float duration, distance;
/**Function that accepts the LED strip brand, the pin the controls
 * the LED strip, and an array of 30 individual LEDs. It also sets
 * the baud rate at 9600 bits per second, and the the initial values
 * of the trigger and echo pins.*/
void setup() {
  FastLED.addLeds<WS2812B, LED_PIN, GRB>(leds, NUM_LEDS);
  Serial.begin (9600);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
}
/**Function loop that the sends a signal from the sensor, calculates
 * the distance, and calls functions responsible for lighting the LED
 * strip based on the distance of an object.*/
 //*****************************SECTION 2*********************************
```

```
 //*****************************SECTION 2*********************************
void loop() {
  // Write a pulse to the HC-SR04 Trigger Pin
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  // Measure the response from the HC-SR04 Echo Pin
  duration = pulseIn(echoPin, HIGH);
  /**Determine distance from duration (Use 343m/s for the speed of sound).
   * Divide duration by two because we are measuring only the distance
   * between the sensor and the object (i.e. half the time the echo pin
   * is set to high).*/
  distance = (duration / 2) * 0.0343;
  if (distance <= 400) {
    light_strip_red();
  }else{
    light_strip_green();
  }
}
/**Sets all 30 LEDs on the strip to green in a wave-like pattern
 * when the sensor doesn't detect an object within a 400cm range.*/
void light_strip_green() {
  for (int i = 0; i <= 29; i++) {
    leds[i] = CRGB(0, 255, 0);//Set LEDs to green.
    FastLED.show();
    delay(2);
    leds[i] = CRGB(0, 0, 0);//Reset LED to black or off
    delay(0);
  }
}
/**Sets all 30 LEDS on the strip to red in a wave-like pattern
 * when the sensor detects an object wihtin a 400cm range.*/
void light_strip_red() {
  for (int i = 0; i <= 29; i++) {
    leds[i] = CRGB(255, 0, 0);
    FastLED.show();
    delay(2);
    leds[i] = CRGB(0, 0, 0);
    delay(0);
  }
}
```

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