ECE 445

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Project Proposal:
Monitoring System for Bicycles

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Problem:

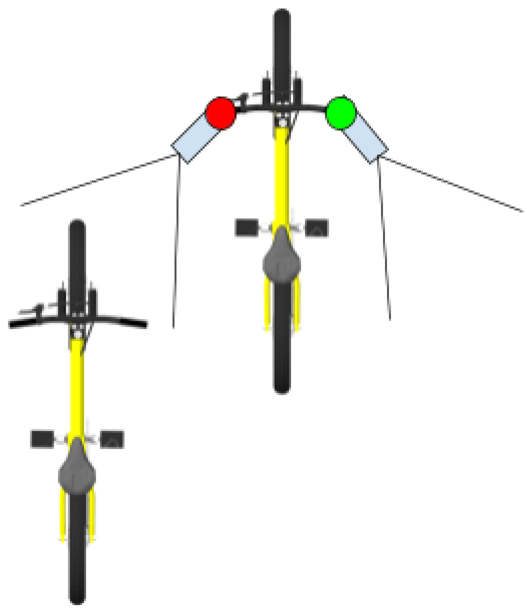
Bicycle monitoring systems are becoming increasingly important for enhancing cyclist safety on the road. However, most bicycles currently lack advanced safety features that help cyclists navigate traffic, avoid collisions, and deter theft or vandalism. According to the National Highway Traffic Safety Administration, thousands of cyclists are injured or involved in accidents each year due to cars and other vehicles in their blind spots. Additionally, bicycles parked in high-risk or unfamiliar areas are often vulnerable to theft or vandalism. Our idea is to build a comprehensive bicycle monitoring system that can be easily installed on any bike, providing cyclists with improved safety and security both while riding and when their bike is parked.

Solution:

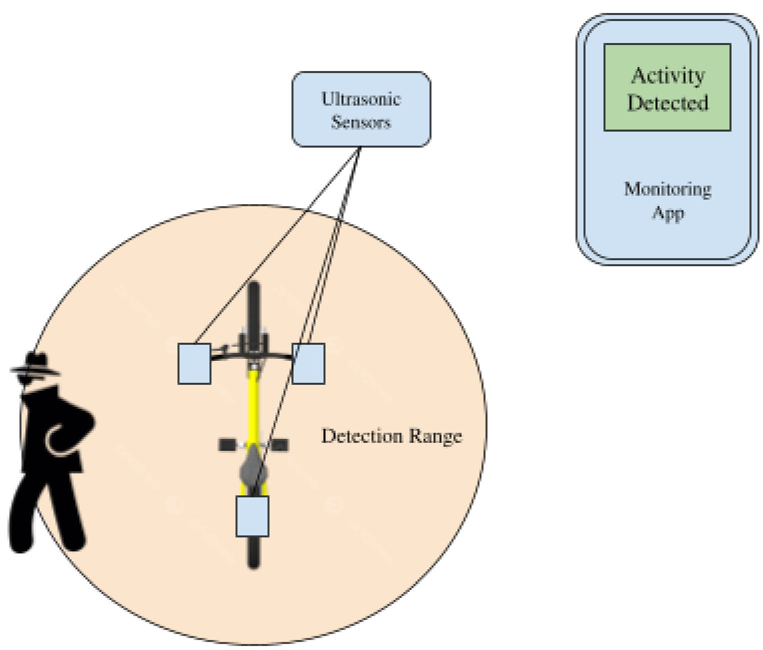
We propose to develop a blindspot detection and monitoring system equipped with sensors that alert cyclists when another vehicle or obstacle is in their blind spot. The system will use a combination of LEDs mounted on the handlebars or helmet and audible alerts, such as a beeping noise, to notify cyclists of potential hazards. A compact control unit will process real-time sensor data to determine if an obstacle is present in the blind spot. We will use ultrasonic sensors with adjustable sensing distances, which can be customized through a companion mobile application. Additionally, the mobile application will offer riding analytics, such as the number of close calls, the side on which more detections occur, and other metrics to help cyclists improve their riding habits. To further enhance bicycle safety, we will integrate an "Away From Bike" (AFB) subsystem. This subsystem will utilize the same sensors to detect motion or activity around the bicycle while it is parked. If any motion is detected, the system will send an alert to the cyclist's mobile app. This feature provides an extra layer of security for cyclists when parked in unfamiliar or high-risk areas, ensuring bicycle safety even when the bike is not in use. By combining blindspot detection, riding analytics, and the AFB system, our solution provides a comprehensive monitoring and safety package that can be easily retrofitted to any bicycle, significantly enhancing road safety and bicycle security.

Visual Aid:

- **Blind Spot Monitoring**



- **AFB System**



Block Diagram:

High-Level Requirements:

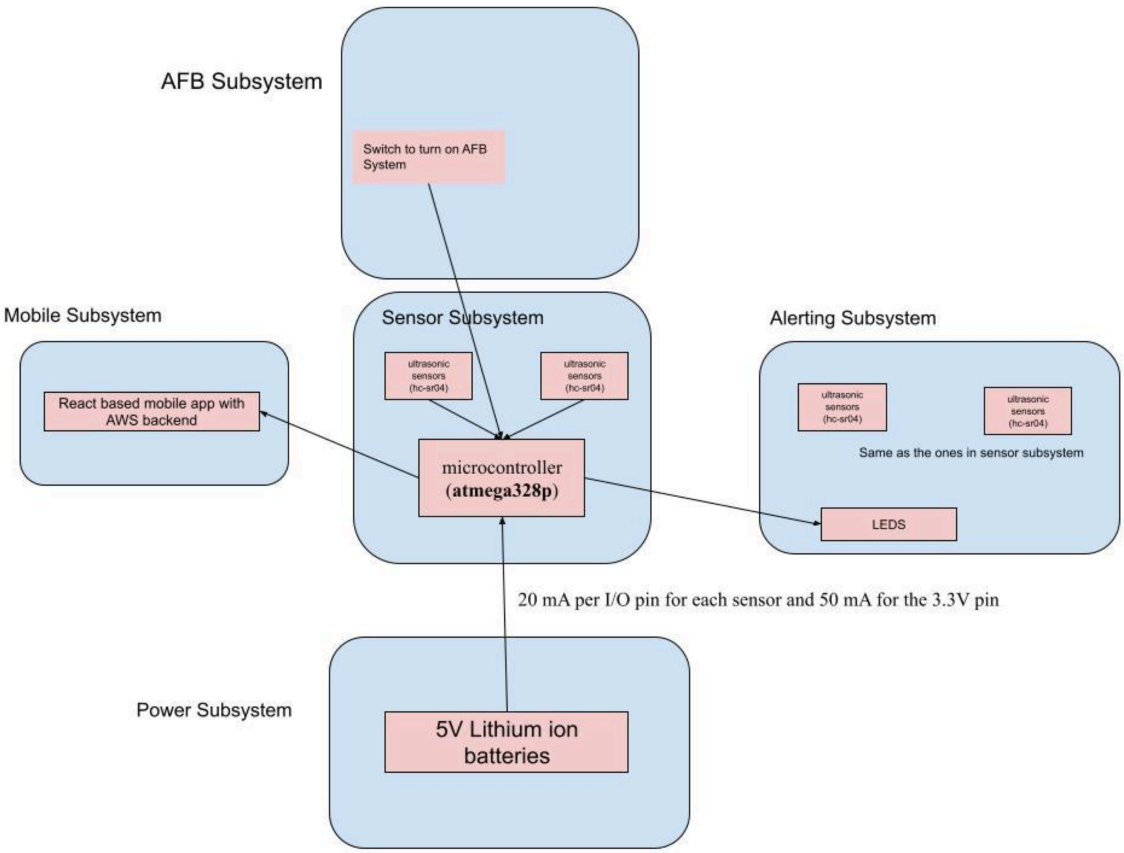
- **Blind Spot Detection and Alerting**: The system shall accurately detect obstacles or vehicles in the cyclist's blind spot within a 3-meter radius and provide real-time visual (LED) and audible alerts within 1 second of detection. The ultrasonic sensors will have an adjustable detection distance that can be configured.

- **Away From Bike (AFB) Monitoring**: The system shall monitor motion around the parked bicycle sending an alert to the mobile application within 3 seconds if any motion is detected, ensuring real-time security when the bicycle is not in use. The AFB system will use ultrasonic sensors to form a radius around the bike. This range will be known as the detection range.

- **Alerting System and Mobile App:** The mobile application shall display riding analytics and provide an intuitive interface for managing system features.The alerting system will accurately flash the LEDs when an object is detected.

Subsystem Overview:

Block Diagram



Subsystem 1 - Sensor Subsystem

This project will feature an array of ultrasonic sensors (**hc-sr04**) on each bike handle that are designed to detect objects at various distances around the bicycle. The sensors will transmit real-time data to a microcontroller (**atmega328p**) for processing, allowing for accurate blindspot detection. The sensors will be strategically placed on the handlebars or helmet for optimal coverage. Additionally, the sensors will be used in multiple modes, including active monitoring while riding and motion detection when the bicycle is stationary (as part of the AFB system). Each sensor module will transmit data to the receiver module contained on the microcontroller.

Requirements:

- The ultrasonic sensors must be able to continuously monitor the area within 3 feet of the bicycle to detect other objects.

- This requires a constant transmission of signals to the receiver module to provide real-time updates.

Subsystem 2 - Mobile Application

We will develop a companion mobile application to enhance user experience and safety. Through this app, users will be able to receive riding metrics, such as the number of close calls and which side of the bicycle had more detections. Additionally, the app will deliver notifications when the AFB system is triggered.

Requirements

- The system must be able to receive notifications from varying distances.
- The riding metrics must be delivered after each biking session.
- The interface must be intuitive and easily comprehensible.

Subsystem 3 - AFB "Away From Bike" System

This subsystem uses the same sensors employed for blindspot detection to monitor motion or activity around the bicycle while it is parked and turned off. If any movement is detected, the system will send an immediate alert to the cyclist's mobile app, providing a sense of security in high-risk or unfamiliar areas. The AFB system is designed to provide real-time protection and is configurable via the mobile app for activation or deactivation based on user preferences.

Requirements

- We will reuse the ultrasonic sensors to create a detection range of 3ft around the bike.
- The power subsystem must deliver power to the sensors even when the bike is not in use when this system is turned on.
- The AFB system must be able to toggle on/off via a switch.

Subsystem 4 - Alerting System

The alerting system includes two LEDs mounted on the handlebars that will light up based on data received from the sensors to visually alert the cyclist of potential hazards. In addition, a small speaker or vibrating motor connected to the control unit will output a synchronized audible or tactile alert (e.g., beeping sound or vibration) when an object is detected in the blind spot. The alerting system will function both while riding (for blindspot warnings) and when the bicycle is parked (as part of the AFB system). The intensity and frequency of the alerts can be configured through the mobile app to suit user preferences.

Requirements

- The LEDs must accurately flash when there is an object in the blindspot of the bike (3ft).
- The LEDs must flash on the side that the object appears in. The flash will be red if there is a detection.
- The system must be able to send notifications to the mobile application when the AFB system is toggled on.

Subsystem 5 - Power System

We will use rechargeable lithium-ion batteries to power the system. The batteries will provide 5V to power the sensors and microcontroller. The system will feature an on/off switch to conserve power when not in use, ensuring the system is long-lasting. The mobile app will provide battery status and alert the user when it requires recharging.

Requirements

- The power subsystem must have separate systems for powering the microcontroller and each sensor module.
- The power delivered to the microcontroller must be 20 mA per I/O pin and 50 mA for the 3.3V pin.
- The HC-SR04 ultrasonic sensor has a maximum current draw of 20 milliamps (mA), so the power subsystem must deliver that to each sensor in the module.

Tolerance Analysis:

Tolerance Analysis:

Microcontroller Capability:
The ATmega328P operates at a clock speed of 8 MHz, which provides the processing power needed to handle the ultrasonic sensors' data in real-time.

Sensor Data Rate Calculation:

- Each HC-SR04 sensor sends an echo pulse that requires processing by the microcontroller to calculate the distance.
- The pulse length corresponds to the distance measured (in microseconds) and needs to be interpreted at least 20 times per second per sensor for real-time monitoring.

4 sensors operating:

- Data Rate per Sensor:
  - 20 measurements/second × 2 data points (trigger and echo) × 4 sensors = 160 data points per second.
- Processing Requirements:
  - Each measurement consists of the time for the microcontroller to handle the trigger signal, listen for the echo, compute the distance, and update the alert status.
  - Time for Processing:
    - The ATmega328P typically requires around 1,000 clock cycles per measurement due to calculations, comparisons, and triggering events.

Microcontroller Clock Cycles:

- Clock Speed: 8 MHz = 8 million cycles per second.
- Cycles Available per Measurement:
  - 8,000,000 cycles/sec ÷ 160 measurements/sec = 50,000 cycles per measurement.
- Required Cycles:
  - Only 1,000 cycles are required per measurement, meaning that the microcontroller still has 50x more processing time available than required for each data point. This provides ample headroom for additional tasks like updating the alert system, sending data to the mobile app, and handling AFB system triggers.

I/O and Communication Capabilities:

- The ATmega328P supports multiple communication protocols such which will be used to communicate with the alerting system and mobile app.
- Data Rate to Mobile App:
    - Assuming an alert packet size of 32 bytes, each alert sent to the app occurs less frequently compared to sensor measurements.
    - Even if the system sends up to 10 alerts per second, this would only require 320 bytes per second (2.56 Kbits/sec), which is easily manageable within the communication capabilities of the microcontroller.

Power System Requirements:

- The HC-SR04 sensors require a maximum current draw of 20 mA each, and the microcontroller's I/O pins are rated to handle 20 mA per pin.
- With 4 sensors operating, the power system must provide:
    - Sensors: 4 × 20 mA = 80 mA.
    - Microcontroller and peripherals: approximately 50 mA for the microcontroller + additional load from the alerting system (LEDs, speaker, etc.).
    - Total Power: Approximately 150-200 mA, within the capabilities of a standard rechargeable lithium-ion battery, which provides sufficient operating time.

Ethics and Safety:

Ethical Considerations:

In accordance with the IEEE Code of Ethics, we as a group pledge to "uphold the highest standards of integrity, responsible behavior, and ethical conduct" when designing, testing, and building our monitoring system.

We are committed to user safety by ensuring our system enhances safety without introducing new risks. False alerts could cause erratic cyclist behavior, potentially leading to accidents. Rigorous testing under diverse conditions (e.g., weather variations) is necessary to minimize such risks [IEEE Code of Ethics, Section I.1].

Collecting and storing riding metrics requires strict data privacy measures. We will use encryption and provide transparent privacy policies, allowing users to control their data. Ethical responsibility includes protecting user information from unauthorized access and misuse [ACM Code of Ethics, Section 1.6].

Safety Concerns:

The system must operate reliably under various conditions to avoid false or missed alerts. We will adhere to IEEE 1609 standards for reliable vehicular communication and conduct environmental testing to ensure consistent performance [IEEE 1609.0].

EMI can affect system reliability and safety. We will test for compliance with FCC regulations to ensure our system does not interfere with other devices [FCC Part 15].

Using lithium-ion batteries requires compliance with safety standards like UL 1642. We will implement overcharge and short-circuit protection to mitigate the risk of fire or explosion.

Our system will comply with applicable state and federal regulations, such as the Illinois Vehicle Code, to ensure it does not interfere with road safety requirements. We will also follow ISO 4210 standards to ensure the system's structural safety on bicycles