UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

ECE 445 : Bike Assist

DESIGN DOCUMENT

Jason Yang **Justin Young** **Kush Gupta**

Teaching Assistant: Shuai Tang

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1 Introduction

1.1 Problem and Solution Overview

Currently, cyclists and motorcycle riders face many difficulties while traveling on the road. While there exist a number of creative solutions that work to improve the safety of those who use alternative transportation on the road by working to improve visibility/other facets of biker safety, none of these solutions focus on the users ability to be conscious about their blind spots without directly observing their surroundings. For example, this poses a problem due to the fact that it prevents the user from keeping their eyes on the road ahead of them, where the highest risk of an accident exists. Furthermore, bikers may also misjudge the amount of leeway they have while attempting to turn, and others who are not paying attention to the roads in front of them or do not notice cars/other objects in their immediate vicinity are in danger of being in an accident. Each of these scenarios presents an opportunity for an accident to take place. Our goal and focus of this project is to reduce the number of accidents by bicyclists down to zero by providing a medium of increased awareness to their surroundings.

Our goal of increased biker awareness will be achieved by our product in two fronts: a proximity detection unit that alerts bikers when other objects or people are in their immediate vicinity, and a turn signaling unit that provides allows for bikers to display their intentions. These units will be bundled into a single attachment that will be able to sit on an adult or adolescent bicycle and provide the aforementioned information. This information will come in the form of loud beeps that speed up as objects move within a distance threshold. The accessory will also house two directional-lights that activate upon button press and allow for the users to signal to others when they will turn left or right, and these buttons will sit one on each handlebar.

1.2 Background

Statistics show that currently, approximately 14 million Americans ride their bike over twice a week, with over 100 million cyclists per year [9]. However, the number of reported accidents is staggering. These accidents can stem from anywhere such as the daily commute or a leisurely night-time ride. In fact the NHTSA reports that each year there are approximately 55,000 accidents, with an average of 857 fatalities [1]. In California alone, there were 12,000 per year on average between 2007 and 2013 [4].

The current solutions and existing laws and structures do not do enough to mitigate the issue of bicycle safety. While there currently are existing solutions that do provide a similar methodology to our own turn signalling system, such as Blinkers and Safe-Tee, they prove not to be as effective as others would like and have even gone bankrupt [10]. Our approach to combatting this issue is to focus on how other mediums on the road are able to reduce accidents. The prime example is cars. At this point in time, most newer cars come with some form of blind-spot detection. In fact, consumer studies show that over 85% of new models come with this feature, with some owners even saying that it is the safest system they've ever used [8]. Furthermore, the product indeed works, allowing drivers to be able to read the roads and travel more safely. In fact, statistics from the IIHS (Insurance Institute for Highway Safety) show that accidents from car lane-changes are down 14% while lane-change accidents with injuries are down 23% [3]. Because of this success, we believe that by bringing over the same idea but instead modeled for bicycles, that we can emulate the same success.

1.3 Visual Aid

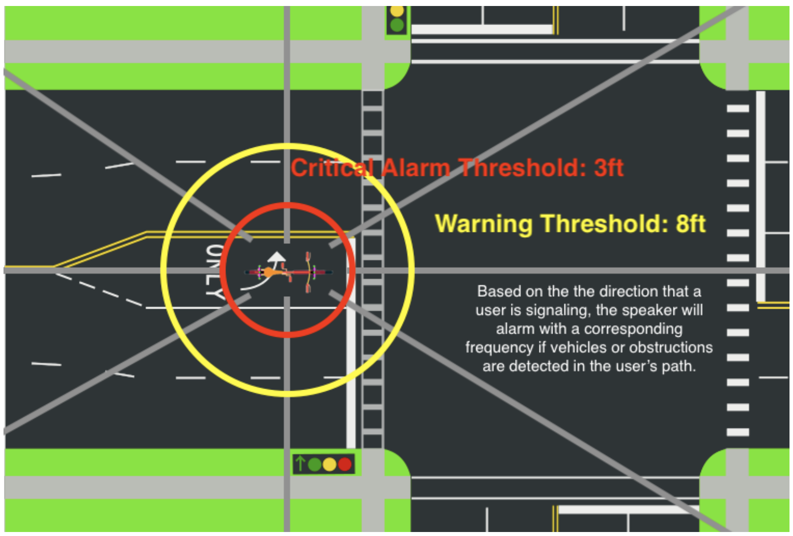

Figure 1: Diagram showing the regions that each ultrasonic sensor will cover as well as the conditions under which varying alarm tones will be made.

1.4 High Level Requirements

- Our ultrasonic sensors must be able to determine whether or not an object is within a threshold of 8 feet, report the actual distance with a granularity of at least 1 foot, and the reported value should be accurate to within .5 feet of the real value, in at most 0.1 seconds.
- When an object or person is registered within the threshold of distance near the user, the speaker system will begin to beep within 0.1 seconds at a volume audible to the user. As the distance decreases down to 3 feet, the beeps from the speaker system will slide up linearly at a rate of 0.5 Hz up to 5 Hz.
- When the user presses the appropriate buttons (left, right turn) the corresponding turn LEDs will light up within 0.3 seconds and must be visible in clear night-time conditions at least 50 feet away facing the front or back of the bike.

2 Design

2.1 Block Diagram

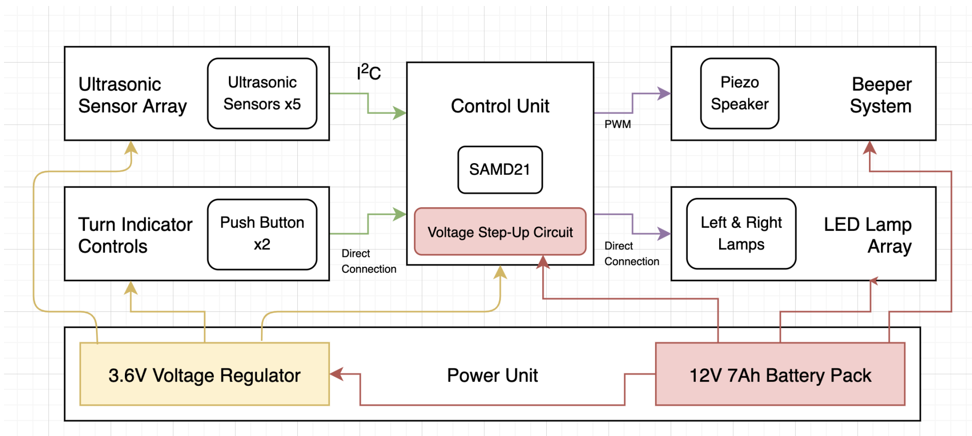

Figure 2: Block Diagram model outlining the interconnections between the subsystems in our design. Note that the red connections denote power lines operating at 12V while the yellow connections denote power lines operating at 3.6V. The purple and green lines denote protocol lines operating at 12V and 3.6V respectively.

The block diagram outlined here shows how we intend to build the proposed product. It shows the modules and interconnections necessary to make the feature-set we imagined possible and to fulfill the high level requirements stated above.

It is composed of 3 overall groups: inputs/sensors, control, and outputs. The sensors are the ultrasonic array and the turn signal buttons used by the user to indicate their actions and for the device to determine if there are any hazards to the user on the road. That data is then used by the control unit to generate a set of outputs to indicate to the user that an obstacle or vehicle is dangerously close, and to show on the LED lamps that the user intends to go in a particular direction. Together, these modules can be used to build a product that will help improve biker safety.

2.2 Physical Design

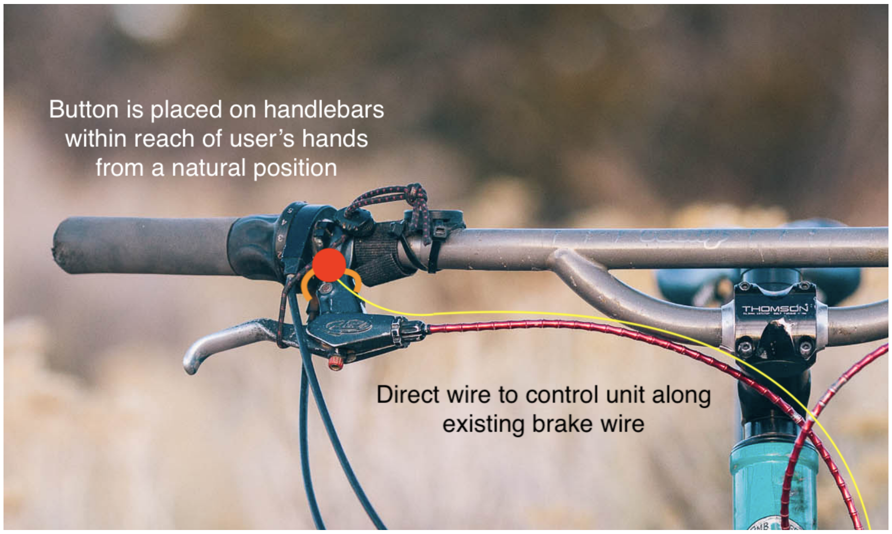

Figure 3: Diagram showing how a turn signal button will be mounted on a bike's handlebars so that a user can activate the turn signals.

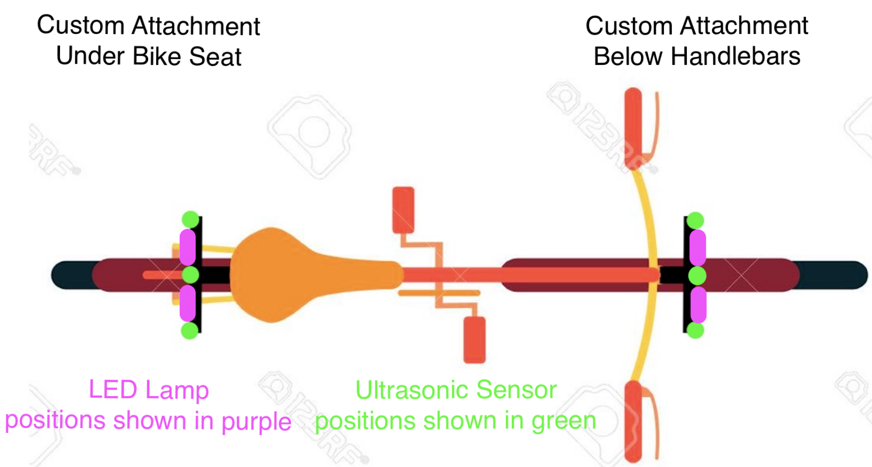

Figure 4: Diagram showing the physical placement of the ultrasonic sensors and turns signals on the bike, with our custom hardware attached to a bike.

2.3 Subsystems

2.3.1 Ultrasonic Sensor Data Ingestion

Ultrasonic Sensor Array
This unit will use ultrasonic sensors to measure the distance between the sensor and other obstacles and vehicles in the road. It must be able to accurately (within .5 feet) measure the distance between the bike and other objects up to 8 feet away. Additionally, it must be robust to false positives which will be implemented by using ultrasonic sensors that are rated for high sensitivity and pairing them with software filtering on the control unit. The filtered data should remain stable within the detection threshold for at least 0.1 seconds in order to register that an object is present. The data will be sent to the control unit via I2C. Our project will incorporate a series of 6 ultrasonic sensors (HC-SR04), three that will face towards the front of the bicycle and three that face the rear of the bicycle. These sensors will provide a range of vision that will allow us to detect other objects that come within this range, and they will be connected via I^2C to an SAMD21 microprocessor.

2.3.2 Control Unit

This is the most critical unit in the design, since it is responsible for sensory ingestion and also for generating outputs that can be used to drive the speaker and LEDs and provide useful feedback to the user and drivers on the road. We plan to implement the control unit in software on a SAMD21 microprocessor, because it is lightweight, has low power requirements, and has a well established community meaning it will be easier to set up and connect to our sensors and other devices.

It will connect to the ultrasonic sensors over a shared I2C bus, and will poll the sensors at a high rate in order to get frequent readings that we will be able to filter to then produce more accurate and stable readings at a rate of at least 20Hz. Based on this, we expect to be able to generate a PWM output signal for the piezo speaker within 0.1 seconds of registering an object within the threshold of 8 feet. The output signal to the speaker will start at a rate of 0.5Hz and increase linearly to 5Hz as the distance from the bike decreases to 3 feet.

It will additionally be responsible for implementing a simple state machine to blink the turn signals in a particular direction after a user presses them. With each press of the button on a side, the signal will stay on for 15 seconds and the LED Lamps on that side of the bike attachment will blink during that time.

2.3.3 Turn Signal Unit

Turn Control Button Array
This unit, in conjunction with the control unit, will be used by the user to indicate when they are going to turn in either direction. The concept used here is very similar to turn

signals in actual vehicles, and the responsiveness of the buttons should match those used in a car. Since these are physical buttons with no special electronics or complicated circuits involved in their operation, we require that the signal generated by the user pressing either should always be transmitted successfully to the control unit to be acted upon.

LED Array
The LED Lamp array will be used to indicate to other vehicles on the road which direction the user intends to turn. When either turn signal button is pressed, the corresponding LED lamp should light up for as long as the button is held, or 10 seconds after the button is released. This allows for the rider to maintain their intent, even when having difficulty finding an opportunity to turn. The LED's will be positioned in a similar manner to break lights on a motorcycle, and is pictured in our physical design. The LED's should be visible in night time conditions up to 50 feet, and in ideal day time conditions up to 25 feet.

2.3.4 Power System

To power the various components in our design, we will require an onboard power supply in our bike hardware attachment. This will be a 12V battery that is capable of providing 7Ah, chosen because it is suitable for driving the LEDs that we specified above at a rating that should have them produce the necessary light to be visible to at least 50 feet as our high level requirements specify. Additionally, the power module will include a voltage regulator for 3.6V that will be used as a logical voltage and power line for the ultrasonic sensors, the push-buttons, and the microcontroller. This is necessary because those components have a lower operating voltage and separate power requirements from the LEDs and the speaker. As mentioned above, the output connections will be stepped up for compatibility across the two power networks.

2.3.5 Speaker System

The speaker system is utilized by our design to alert the user that a vehicle or other obstruction has come close to them. When the control unit registers an object as being within the threshold of 8 feet, it will generate the PWM signal necessary to produce a beeping sound with a frequency corresponding to how close the vehicle is to the bike. The beeping tone produced by the speaker will need to be 80dB in order to be louder than light traffic (typically 75dB). We plan to use a simple piezo-electric speaker to implement this functionality, given that it will be the easiest to connect and to drive via our microcontroller. Additionally, there are no strict requirements about the tone or pitch that the speaker produces aside from it being audible and recognizable to the user. Thus, a piezo speaker is a suitable component for producing a tone of this nature without requiring a complex input signal to be generated by the microcontroller.

2.4 Tolerance Analysis

To validate that our design will be successful, we will analyze its core operating component – the ultrasonic sensing unit. This unit is composed of the sensors itself, as well as the control unit that will perform the real-time sensor fusion to produce meaningful and usable inputs to the internal state machine.

Our approach will focus upon the usage and ability of a single ultrasonic sensor, which can be extrapolated to determine the usability of the series of six ultrasonic sensors in our system.

Consider a single ultrasonic sensor. Based on the datasheet for the ultrasonic sensors that we intend to use, HC-SR04, we can note that the recommended measurement cycle is approximately 60ms. This provides a refresh rate of $1s/60ms = 16.667$ Hz. From our high-level requirements, we need to be able to support the identifying the presence of objects at least 8ft away. We look to prove that our approach satisfies any reasonable user situations by determining which situations our product would be unable to catch. We will determine our system to be successful if we are able to detect other bikers at a rate of at least 99%.

In order for an object to pass over the detection of the ultrasonic sensor, we consider the case in which an object is traveling at some maximum velocity RELATIVE TO THE USER, X. In this case, the object would have been just outside of the 8 ft region when the ultrasonic sensor is measured, and crashes into the user before the next measuring of the ultrasonic sensor. As a result, we note that we can calculate the maximum speed as such:

$$X = \frac{distance}{time} = velocity$$

$$X = \frac{8 \text{ ft}}{0.06 \text{ seconds}} = 133.3333 \text{ ft/s}$$

As a result, we can determine that the maximum speed an object can be travelling is $X = 133.333$ ft/s, or $X = 90.909$ mph, in which below this speed, we would be able to detect, while objects with speeds above, we wouldn't be able to detect.

However, a speed of 90 mph is unreasonable for any other objects on the road. As a result, we look to determine a probabilistic model that takes the input of a given speed of an object and provides the probability that we will detect the object within the 8 ft threshold.

To do this, we will make an assumption regarding the accuracy of our ultrasonic sensors. Under normal circumstances, we would test this accuracy in real-life experiments. However, for the purpose of this analysis, we will assume an accuracy α that is much lower than what it should be, $\alpha = 80\%$. We will define accuracy to mean that 80% of the time, the measurement provided will be correct, and 20% of the time it will be a trash value.

We can see that while travelling at $X = 90.909$ mph, we will be able to have N number of measurements of the ultrasonic sensor, where $N = 1$. Because these relations are linear, we can see that a speed Y will directly determine the value of N. In other words, the speed of the object is inversely proportional to the number of measurements of the object while it is within an 8 ft threshold.

$$N = \left\lfloor \frac{X}{Y} \right\rfloor \text{, where X is the constant}$$

Given a value of N, and that each individual measurement should follow the memoryless property of probability, we can apply a geometric distribution to determine the speed. Let's define a function $F(Y)$ that outputs the final probability of capturing an object given its speed.

$$F(Y) = 1 - \alpha^N$$
$$N = \left\lfloor \frac{90.909}{Y} \right\rfloor$$

Given this formula, we can apply our assumptions to any reasonable scenario given the input of the relative speed of an object, and output a probability. With the scenario that the object is moving at $Y = X = 90.909$ mph, we can assume we will detect the object with an 80% accuracy.However, remembering our end goals, we look to determine the probability we will be able to capture other bikers. From our research, we can determine that the average speed of a biker is approximately 13.5 mph. Given this, we can say:

$$N = \left\lfloor \frac{90.909}{13.5} \right\rfloor = 6$$

$$F(13.5) = 1 - 0.20^6 = 99.9936\%$$

We can see easily how even with this poor assumption regarding the accuracy of the ultrasonic sensor, that we are easily able to surpass our value of a 99% accuracy when detecting bikers. Realistically, the accuracy of the sensor should be much higher, which would only strengthen our result. As a result, we can confidently say that from our mathematical analysis, our system has a high probability of detecting objects within the threshold.

2.5 Requirements and Verification

2.5.1 Sensors

Ultrasonic Sensors

Requirements	Verification
Each ultrasonic sensor should report distance data at a rate of at least once every 60ms in order to detect objects and obstructions within their field of view.	We will directly obtain the values reported by an ultrasonic sensor driven by a trigger once every 60ms over a fixed time interval of 10 seconds and confirm that at least 166 samples are recorded.
The ultrasonic sensor measurement granularity should be smaller than 1 foot. This will allow us to discern that an object or obstacle has moved relative to the biker.	We will take a series of ultrasonic sensor measurements and move the sensor base until we can register a consistent difference in the reported value that can then be replicated over at least 10 trials. The physical length of this adjustment represents the granularity of the ultrasonic sensor measurement.
The sensors should be able to meet the above requirements when tested where the objects are placed an angle of at least 10° away from the sensor face's normal direction. Thus, the field of view over which accuracy is maintained should be at least 10°.	We will repeat the testing steps described above where the obstructions are placed at an angle of 10° away from the sensor normal. The sensor is expected to be able to satisfy the provided constraints under these conditions.

Turn Buttons

Requirements	Verification
Each button should trigger an interrupt on the SAMD-21 microcontroller when a user holds the key down for at more than 0.2s. A short press is considered 0.5s, but a shorter activation period will ensure greater safety for the user.	We will write s simple program for the SAMD-21 that fires an interrupt when the button input signal is pulled low to test this, by counting the number of interrupts fired over the course of execution and comparing that to the number of times the button was pressed. These numbers should always match up for 'full' button presses that last at least 0.2s.

Control Unit Software

Requirements	Verification
A program running on the SAMD-21 must be able to generate a trigger input for the ultrasonic sensors once every 60ms. This will be used to drive the sensors and request values at that rate.	We will write a test program to generate this trigger signal for the ultrasonic and verify that the output satisfies the constraints of the physical ultrasonic sensors. This will be tested in conjunction with the first Requirement & Verification entry for the ultrasonic sensors.
The generation of output signals for the LED lamps and speaker must be completed within 40ms of when the inputs are originally derived from the ultrasonic sensors. This will ensure delivery of outputs to the user within 0.1s overall.	We will write a test program to take a set of arbitrary sensor inputs and generate the necessary output signals to power the LEDs and speaker, once every 200ms. These generated signals can then be verified using an oscilloscope to ensure that they are accurate and meet the timing constraints provided.
Software will move through a simple finite state machine between an idling state, right turn state with no potential dangers, left turn state with no potential dangers, right turn state with potential dangers, and left turn state with potential dangers.	We will compare the expected output state to the actual output state based on a series of pre-defined inputs.
The software should be capable of communicating its internal state information between micro controllers (such as object detection, between the LED controller and the ultrasonic sensor controller) via a simple serial connection.	We will verify that data was successfully transmitted via serial connection through the micro controller by checking the output signals to see if there was any data loss.

2.5.2 LEDs

Requirements	Verification
LEDs should produce at least 50 lumens of light energy when fully powered on and set to the color white.	We will use a Lux meter to verify this requirement directly.
LED indicators should be visible to others both in front and behind the user at a distance of 50 feet in ideal nighttime conditions, up to 25 feet in ideal daylight conditions, and up to 10 feet in severe weather conditions.	After the LEDs have been mounted on the bike, we will verify this requirement by observing the visibility of the LED's at various distances under various weather conditions.

2.5.3 Power

Requirements	Verification
The lithium iron phosphate battery, with the assistance of the voltage regulator circuit should be capable of providing a constant 3.6V of power, as well as 12V directly.	We will directly inspect the power output from our power system over an extended period of time and under different usage constraints.
The battery should power the hardware components and microcontroller for a minimum of 4 hours.	We will leave the system on and time how long the battery lasts.
The system should have an ON/OFF switch enabling the user to save battery when not in use.	We will analyze and confirm the power to each of the on-board components when the switch is in the OFF and ON positions.

3 Cost and Schedule

3.1 Cost Analysis

We estimate that our fixed development costs come out to $50/hr, at about 8 hours of work per week. With our team of three, the project will be completed over a total of seven weeks, up until the mock demonstration. Therefore, our projected costs come out to:

$$3 \cdot \frac{\$50}{hr} \cdot \frac{8hr}{wks} \cdot 7wks \cdot 2.5 = \$21,000$$

We estimate that the total cost of the required parts and prototype PCB for a single unit come out to the following figures:

Table 1: Part Costs for the Prototype Unit

Parts	Cost
Large Piezo Speaker	$7.95
5x Ultrasonic Distance Sensor - HC-SR04	$19.75
SparkFun Qwiic Micro - SAMD21 Development Board	$19.95
Assorted Buttons	$1.60
Lithium Ion Battery - 1Ah	$9.95
Adafruit NeoPixel Digital RGB LED Strip	$16.95
Assorted capacitors, resistors, ICs, sockets, crystals (Digikey; est.)	$10.00
Total	$86.15

Our cost of developing and prototyping this project therefore will cost an estimated $21,086.50. If the project moves forward into mass production, each unit will cost roughly $52.87, after the initial costs of research and development.

Table 2: Part Costs for a Mass Produced Unit

Parts	Cost
Large Piezo Speaker	$7.16
5x Ultrasonic Distance Sensor - HC-SR04	$3.56
SparkFun Qwiic Micro - SAMD21 Development Board	$16.96
Assorted Buttons	$1.44
Lithium Ion Battery - 1Ah	$9.95
Adafruit NeoPixel Digital RGB LED Strip	$13.40
Assorted capacitors, resistors, ICs, sockets, crystals (Digikey; est.)	$0.40
Total	$52.87

3.2 Schedule

In order to complete this project in a timely manner, we have outlined the following schedule. As with any project, we are cognisant that there will be unexpected bugs and challenges, which is why this schedule accounts for two weeks of extra time to resolve these issues. Our plan is to first focus on the hardware components of the project, which will be necessary in order to understand the incoming data. This will allow us to begin extrapolating important and relevant data, while filtering out unwanted noise through our software. We will concurrently design and build our PCB, so that we have all the required components to begin developing our software. Once the hardware is working and functional, we will write code which will be uploaded to our micro controller.

Week	Tasks
4/24/20	Order and test hardware components.
5/1/20	Design and implement LED array PCB using EAGLE.
5/8/20	Attempt to extrapolate significant data from the Ultrasonic sensors, via the micro controller.
5/15/20	Complete PCBway order. Begin implementing software which takes the data from the ultrasonic sensors and warns the user when a moving object is approaching.
5/22/20	Finish writing the software portion of the project, and upload the code to the micro controllers.
5/29/20	Mount all sensors, chips, and power components onto jacket.
6/5/20	Extra time / Final Adjustments
6/12/20	Mock Demo
6/19/20	Final Demo

4 Project Differences

4.1 Overview

Our project focuses on a single key point of providing information to the biker regarding their surroundings. The key notion that is fundamental to our users lies in the simplicity of relaying information from the surrounding environment to the users. We utilize the ultrasonic sensors in order to determine the distance of other objects from the user. This information is relayed to a control unit that determines how far the object is and produces a signal through the speaker system to the user at a speed that increases as the object comes closer, and this signal comes only when the user is attempting to turn. While our project holds semblance to our original project, Project Safe-Tee, as well as other projects that focus on the overarching goal of the safety of cyclists, the new project is fundamentally unique in a number of ways.

4.1.1 Differences from the Original Project

Our project is fundamentally different from our previous project, *Project Safe-Tee*, through its method of relaying information. The previous project focused upon working by providing bikers a method to display their intentions to others on the road. It accomplished this goal by implementing an intuitive gesturing system that lit up a corresponding light signal to allow a biker to indicate when they are going to turn. However, the new project, *Bike Assist*, instead focus upon giving the bikers new information and increasing their awareness of their surroundings. The focus here is our proximity detection system, which we will build using ultrasonic sensors and a speaker system. Because the sensors in the previous project were based upon IMUs, **our project is fundamentally different in the way that it captures and relays information**.

The previous project focused upon capturing information from the cyclist, focusing on angles between multiple IMUs, and relays the information from the biker to others on the road, while the newer project captures information from the surroundings using ultrasonic sensors and relays that information to the biker. The other component of our new solution is a signalling system that does have similarities to the other project. However, Project Safe-Tee's signalling system focused upon using gestures, while our newer system will be more light-weight and rely on button-presses. The LEDs will also be mounted in a completely different manner, as the older method sat on a jacket worn by the user, while this would be an attachment to the bicycle itself.

4.1.2 Differences from Other Projects

With the key ideas of our project in mind, we looked a previous projects produced in ECE445 and found a few key components that make our project unique.

Project Bike Crash Detection - Fall 2020
This project produced in Fall 2020 focus upon the detection of the crash of a cyclist. The idea behind the project was to reduce the fatalities by detecting a bicycle crash and notify emergency contacts in a reasonable time frame. Their project utilized a GPS and IMU that provide information to a microcontroller and sends the information to a communication unit. However, the difference lies in the timing of the notification. The Bike Crash detection focuses using the IMU data in order to determine the number of *g's* that a rider may experience, as well as the *dps* (degrees per second) produced by the gyroscope in order to determine a crash. However, our project focuses on preventing the collision in the first place. We look to notify the user before a crash has occurred using a speaker system that depends upon the distance between the user and other objects on the road. This central difference is further represented in the implementation of gathering data, as we use different sensors, as well as the relaying of information. The information for our unit is relayed directly to the biker, while this other recent project looks to inform the appropriate emergency contacts that the user is in trouble.

Traffic Sensing Bicycle Light - Spring 2019
This project was produced in Spring 2019. The goal of their project was to find other

objects on the road (similar to our project) and provide a warning signal to the user regarding an objects impending difference. Their goal is to reduce accidents in a similar sense as well. However, the difference lies in the fundamental approach of our projects. Their project employed a doppler radar sensor in conjunction with the ultrasonic sensors in order to determine velocity and direction of other users. By doing this, they are able to see if something is hurdling towards the user and warn the user if this is the case. However, our project does not look to determine velocity, and instead it focuses upon providing warning regarding all objects, where the metric that defines the severity of the alarm is based solely on distance. Furthermore, our project solely uses a speaker system, which can be consistently heard by the user, while the *Traffic Sensing Bicycle Light* employs a light that must be monitored and checked. Our project Bike Assist provides an extra methodology that lies in the turn signals and lights that would sit on the bike and be activated by buttons on the handlebars.

5 Discussion of Ethics and Safety

In the effort to create a product that is meant to save lives, it is important to consider the safety and ethical components of not only the creation of this project, but also the usage of it by the populus. While building the project, as we are working with electrical components, we run the risk of harm to ourselves and those around us. Our utmost concern will be laboratory training and safety with regards to the Division of Research Safety training [5].

Furthermore, when considering the production of our product, we must adhere strictly to Rule 3 of the IEEE Code of Ethics, which states that we must be "honest and realistic" with our claims with respect to available data [2]. Our plan of development includes extensive experimentation that allows for the easiest and most intuitive usage of Project Safe-Tee. The jacket must always light up when the user brings up his arm, as there is an even greater risk when the user thinks that others on the road can see his turning indicator when in fact they do not. Our project further must follow Rule 9 of the code of ethics, to ensure that our product will neither indirectly cause harm due to missing indicators nor directly cause harm due to malfunctions [2].

We are cognizant that there are multiple concerns that stem from the creation of the project that may directly cause harm to a user. One of the most obvious is short-circuits, as our device is an electrical one that is meant to be used outdoors. As a result, we will ensure that the internal components of our project will be dry while submerged up to 1 meter of water, adherent to the IP67 guidelines [6]. Finally, the LiPo battery is well known for its inherent safety risks, as it is not difficult to start a fire or even an explosion under certain circumstances. To combat this, we will ensure that the charger prevents overcharging outside of the 3.7V range, and we will tell the users basic safety tips, such as to wait for it to cool before charging it after usage, as well as to never leave the battery unattended while charging [7].

In order for our project to meet the criteria we've established, we plan to implement certain safety measures to mitigate risk to the user when the product is both in use and during charging. Firstly, in order to prevent the LiPo battery from overcharging, we plan use a voltage regulator to limit the output of our power source. To prevent the worst case scenario of thermal runaway, which would lead to the battery potentially exploding, we plan to encase the battery in a durable heat resistant material such as leather or mineral wool. Secondly, we decided to use LED's that are assembled in parallel as opposed to LED's assembled in series, so that one failed LED does not compromise the reliability of the product. This makes it so that unless every single diode fails simultaneously, the turn signal indicator will always light up when the button is corresponding button is pressed, given that the rest of the components are functional.

Additionally, if the micro controller handling the LED's recognizes that it is unable to communicate with the control unit, or that the data it is receiving is corrupted, the LED's will blink red to indicate to the user that the product is no longer operational. Similarly, if the control unit recognizes that the ultrasonic sensor array is failing to deliver reliable data, the LED's will blink yellow to indicate that the sensor array is in need of repair. Lastly, in order to clarify to the user how to properly use the product, we could include a brief safety pamphlet to inform the user about the various risks and how to mitigate them.

While the safety risks of assembling this product are minimal, we recognize that there is some form of danger when handling and building electronic components. In order to prevent any injury or harm when assembling this product, we have decided to use electricity resistant gloves.

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