UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN

ECE 445 : Bike Assist

PROPOSAL

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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.

1.2.1 Distinguishing Our Project

Our project is fundamentally different from our previous project, *Project Safe-Tee* in a number of different ways. The previous project focused upon working by providing bikers a method to display their intentions to others on the road. However, this project 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.

1.3 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

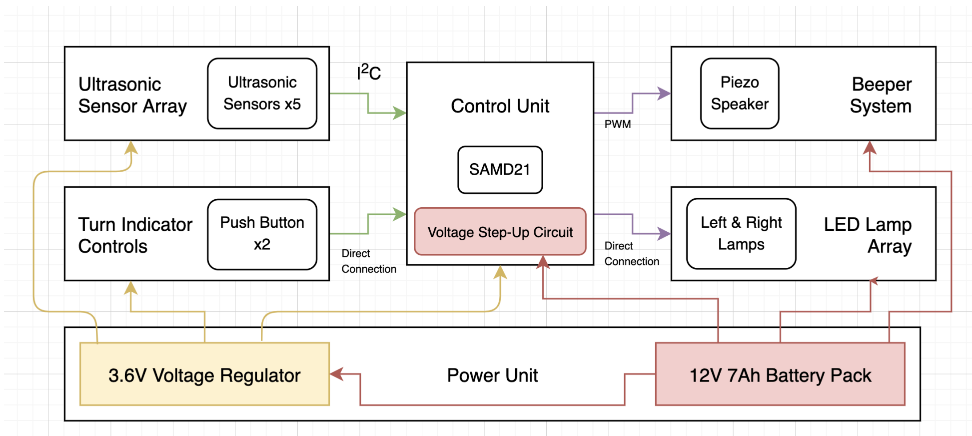

Figure 1: Block Diagram model outlining the interconnections between the subsystems in our design. Note that the red connections denote power lines operating at 12V while the yellow connections denote power lines operating at 3.6V. The purple and green lines denote protocol lines operating at 12V and 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

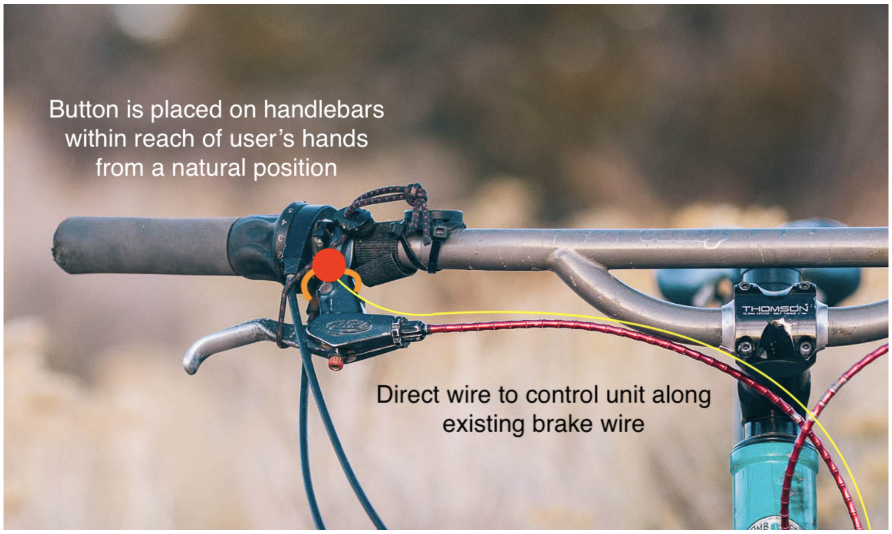

Figure 2: Diagram showing how a turn signal button will be mounted on a bike's handlebars so that a user can activate the turn signals.

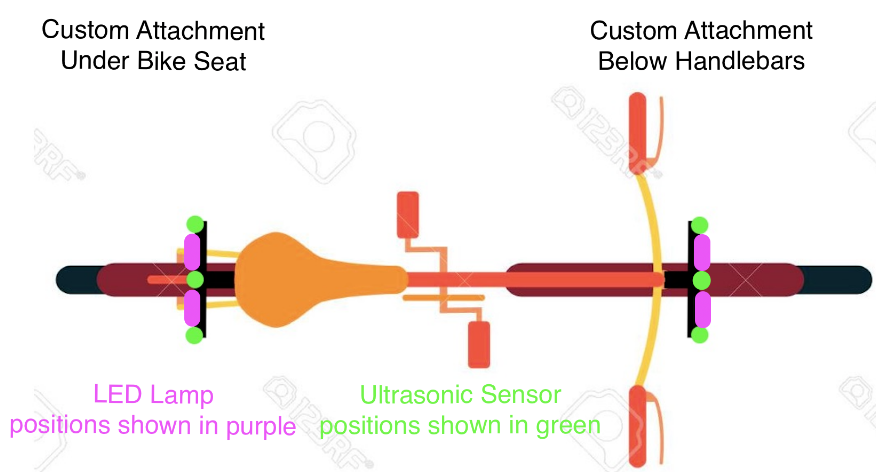

Figure 3: Diagram showing the physical placement of the ultrasonic sensors and turns signals on the bike, with our custom hardware attached to a bike.

2.3 Design

As described above, our design is modular to support being able to build it easily and test each part individually before connecting them together to assemble the complete product. Below we will outline some requirements that each of the blocks have in order for the full design to work properly.

The sensory components will be used to ingest data from the bike's surroundings and about the user's intentions, after which the control unit will be responsible for turning those inputs into actionable output signals that the speaker module and LEDs will then use to alert the user of nearby obstacles and vehicles, as well as alert others on the road to the biker's intention to turn in a particular direction.

This design allows for each of these blocks to operate independently, and for communication to be done between them either via a dedicated bus and I2C protocol (in the case of the ultrasonic sensor array), or direct connection and PWM (for the piezo speaker) or simple digital signals (for the buttons and LEDs).

2.3.1 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.

2.3.2 Turn Controls

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.

2.3.3 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.
Also, to be able to produce signals that are suitable for driving the LEDs and the speaker, we will also require a simple voltage step up circuit on each of the SAMD21's output pins that are in use. This circuit will be responsible for taking an input signal of 3.6V and stepping it up to a range of up to 12V which will be compatible with the speaker and LEDs that we will use in those modules respectively. The step-up circuit will be powered via the 12V battery directly.

2.3.4 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.

2.3.5 LED Lamp 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.

2.3.6 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.

Based on our estimation, given that vehicle headlights use up to 70W of power, we expect that the LEDs should be able to produce a comparable output with a battery like the one described above, rated for 84W over one hour. In practice, the actual power draw might be different, however the separation of logical and direct power nets in our design allows for adjustment of the battery, speaker, and LED voltage without affecting the other components in the design.

2.3.7 Risk Analysis

Due to the complexity of tracking moving objects in real time, the ultrasonic sensor array poses the greatest risk to the successful completion of our project. Not only will the sensor array have to filter out unwanted noise, it must also be able to accurately determine the difference between stationary objects and moving vehicles. This is particularly important because the sensor array is looking to identify vehicles as opposed to easily avoidable obstacles. Furthermore, if the sensors have difficulty identifying fast moving objects, the warning speaker may not trigger at all for vehicles moving faster than a certain speed, which could pose a large risk to users biking near expressways, or any roads where cars are moving fast.

3 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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