Environmental Sensing for cyclists

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1. Introduction

1.1 Objective:

Bicycles are one of the best ways to use as a method of transportation or just for recreational use, however, when you're on a bicycle, you are more susceptible to dangers on the road due to poor visibility and less protection than that of a car.

Looking behind you while on a bike increases the risk of an accident because even a few seconds of not looking in front of you is all it takes for an accident to happen, which can cause the cyclist to sustain long term injuries and heavy medical bills. There are currently countermeasures for preventing these problems right now such as the "Garmin Varia Rear-view Radar Rear Bike Light" which you can get on the market for 200$, however this product will alert you of cars behind you via warning lights flashing on the GPS fitted onto the bike, but it requires the user to look down and spend precious few moments of not paying attention to the road ahead, which is still dangerous.

Our group aims to reduce the risk of riding a bicycle so that cyclists will not need to constantly look behind them, yet, they will still know when and which direction a vehicle is approaching behind them, and they will always be able to focus on the road ahead of them.

This device will have two components: one part will detect hazards from behind using sensors fitted onto the bike itself, the other component will be an Attachable Haptic Feedback that the cyclist will wear which will have an array of motors that vibrates with varying frequency depending on the direction of the hazard and the distance of the hazard so the cyclist will know whether to swerve right or left to avoid the approaching vehicle.

1.2 Background

Based on statistic by the National Highway Traffic Safety Administration (NHTSA)[1], The number of bicyclists killed in 2015 rose by 12.2 percent from the year before, totaling 818 who died in crashes which increased from 729 cyclists killed in 2014, this does not account for cyclist injuries. Estimated cyclist injuries was around 45,000 in 2015, and the total cost of bicyclist death and injury is over $4 billion per year.

There are already countermeasures to minimize bicyclist injury and death such as helmets and a radar sensor that you can get for $200 dollars which also comes with a GPS, but you will need look down at the flashing LEDs constantly to know whether there was a vehicle behind you, and the GPS seems unnecessary for a bike since a smartphone can do the same along with many other functions.

1.3 High level Requirement

We decided that the vest idea might be too difficult to implement and uncomfortable for the user, especially with the electronics digging into the user's body, thus we will test different ways to integrate the electronics and the motors for the user to wear. The options we have are the belt or the wearable wrist watch that will hold all the electronics and motors. This will be generalized as an attachable haptic feedback(AHF). We called it the AHF because the product will be attached to the user's body in a way we find to be most aesthetically pleasing and ergonomic. Haptic means that the user will receive vibrations to receive information, and feedback is because the user will be given information based on sensors receiving information that is useful to the user.

- The device must be able to detect vehicles up to 4m behind the bicycle in order to give sufficient warning to the bicyclist about vehicles behind said cyclist. The detection will also need to detect vehicles on the side but not as far as the sensors behind.
- The sensors will need to be able to communicate with wireless signals to the motors within the Attachable Haptic Feedback with short or no time delay in order to alert the bicyclist about vehicles from behind instantaneously.
- The vibrations in the Attachable Haptic Feedback that are caused by motors will need to vibrate at varying frequencies depending on how far away vehicles are behind the bicyclist, if the car is further away, i.e 3-4m, the motors will have a low vibration frequency, but the user will still feel it, from 1-3m, the motors will vibrate with more frequency warning the cyclist to maneuver away from that direction. The Bicyclist who will be wearing the Attachable Haptic Feedback will then feel the vibrations for an extended period of time, indicating that there is a vehicle behind the user.

2.Design

2.1 Block Diagram

We plan to separate the system into the two modules, the sensing module in hooked on a bicycle and has one bluetooth module, three-direction ultrasonic sensor pointing to three different directions, and a power supply. And the Attachable Haptic Feedback part has three vibration motors which indicate hazard from different directions to the cyclist. It also has a receiver to receive the bluetooth signal from the sensing module.

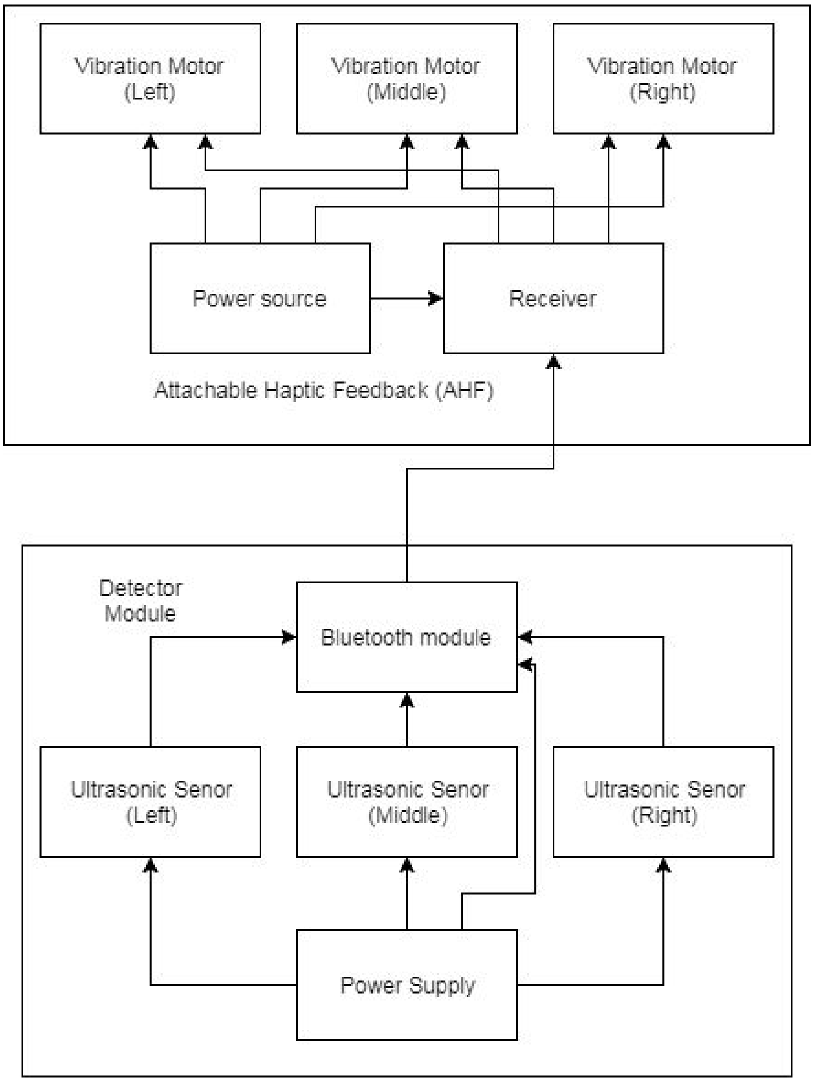


Fig 1. Block Diagram

2.2 Physical Design

The Attachable Haptic Feedback that the cyclist wears will need to hold all the electrical components. The Attachable Haptic Feedback will need to be waterproof in case the bicyclist encounters rain while riding the bike, therefore protecting the electronics from water damage.

The case that will be latched onto the bike will also need to be waterproof in order to protect the electronics within. The case for the sensors and the AHF will need to be made by the electronics shop and whether we receive it for the demo will depend on how busy they are because other projects may be more heavily reliant on their services. Thus, we may need to make do with a cardboard box casing for the final model. We are planning to mount the AHF under the seat which is roughly the same level as the flat surface on the front of a car or motorcycle. And the haptic motor will be mounted close to the inside of the belt or wristband to make the vibration more noticeable.

2.3 Functional Overview

Attachable Haptic Feedback Part/Vibration module

The vibration motor module offer various vibration frequencies depending on the distance of objects behind the cyclist. Since the motor is controlled by PWM, we can adjust the frequency of the motors easily. Since the motor is in a Attachable Haptic Feedback, we need some kind of stronger motor, and eccentric rotating mass vibration motor (ERM) will do the job.

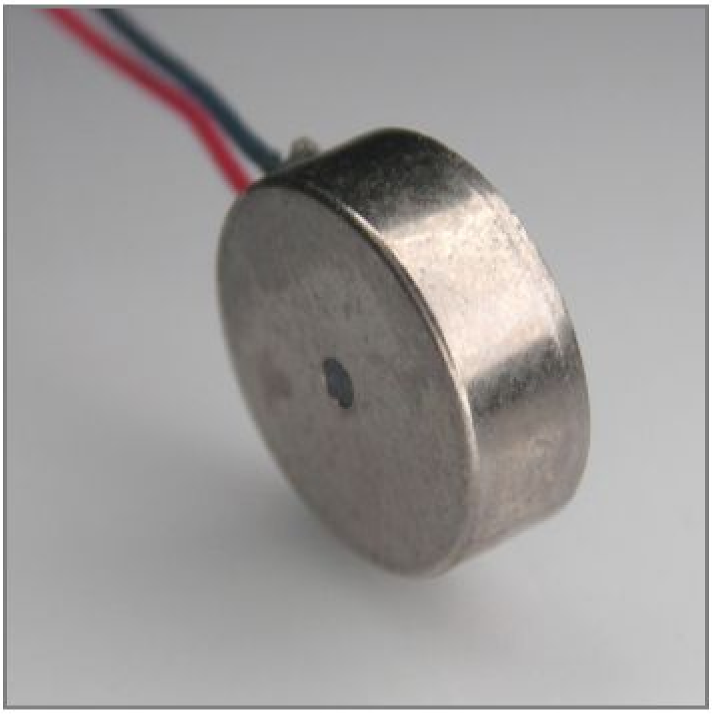


Fig 2. Physical View of Flat Motor

Specification	Value
Voltage [V]	3
Frame Diameter [mm]	10
Body Length [mm]	3.4
Weight [g]	1.2
Voltage Range [V]	2.5~3.8
Rated Speed [rpm]	12000
Rated Current [mA]	75
Start Voltage [V]	2.3
Start Current [mA]	85
Terminal Resistance [Ohm]	75
Vibration Amplitude [G]	0.8

Fig 3. Example Specification of Flat Motor

The bluetooth receiver will receive the signal from the outside bluetooth module, which tells you which direction the potential hazard is, then it will control which motor to vibrate. In the Attachable Haptic Feedback, the power module is likely to be a battery which can supply power to both the vibration motor and receiver.

Detector Part

The detector case will have ultrasonic sensors that will detect objects in three directions. This is necessary because objects will approach bicyclists' blind spots from three directions(directly behind, and the right and left sides). After sensing hazards from behind or the sides, the signal will be sent to the bluetooth module, which is used for communication between two larger parts.

The bluetooth module that we may use will probably be bluetooth 4.0, which has a higher refreshing rate and more stability. Because there are no mechanical parts involved in the detector case, we only need to use the battery as a power source to power things up.

We have done research on the different types of UltraSonic ranging sensors and have purchased them, but have yet to perform tests on these. However we do have their specifications and data sheets available which have the functionalities we require for our project.

Fig 4. 6.5m long US sensor(for detecting objects behind bicycle)

Features

- Continuously variable gain for control and side lobe suppression
- Object detection to zero range objects
- 2.5V to 5.5V supply with 2mA typical current draw
- Readings can occur up to every 50mS, (20-Hz rate)
- Free run operation can continually measure and output range information
- Triggered operation provides the range reading as desired
- Interfaces are active simultaneously
- Serial, 0 to Vcc, 9600 Baud, 81N
- Analog, (Vcc/512) / inch
- Pulse width, (147uS/inch)
- Learns ringdown pattern when commanded to start ranging
- Designed for protected indoor environments
- Sensor operates at 42KHz
- High output square wave sensor drive (double Vcc)
- Actual operating temperature range from –40°C to +65°C, Recommended operating temperature range from 0°C to +60°C [1]

Benefits

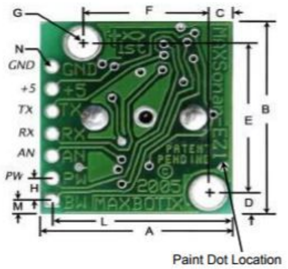
- Very low cost ultrasonic rangefinder
- Reliable and stable range data
- Quality beam characteristics
- Mounting holes provided on the circuit board
- Very low power ranger, excellent for multiple sensor or battery-based systems
- Fast measurement cycles
- Sensor reports the range reading directly and frees up user processor
- Choose one of three sensor outputs
- Triggered externally or internally

Applications and Uses

- UAV blimps, micro planes and some helicopters
- Bin level measurement
- Proximity zone detection
- People detection
- Robot ranging sensor
- Autonomous navigation
- Multi-sensor arrays
- Distance measuring
- Long range object detection
- Wide beam sensitivity

Notes:
[1]Please reference page 4 for minimum operating voltage verses temperature information.
[2] Please reference page 12 for part number key.

LV-MaxSonar-EZ Mechanical Dimensions



A	0.785"	19.9 mm	H	0.100"	2.54 mm
B	0.870"	22.1 mm	J	0.610"	15.5 mm
C	0.100"	2.54 mm	K	0.645"	16.4 mm
D	0.100"	2.54 mm	L	0.735"	18.7 mm
E	0.670"	17.0 mm	M	0.065"	1.7 mm
F	0.510"	12.6 mm	N	0.038" dia.	1.0 mm dia.
G	0.124" dia.	3.1 mm dia.	weight, 4.3 grams		

Part Number	MB1000	MB1010	MB1020	MB1030	MB1040
Paint Dot Color	Black	Brown	Red	Orange	Yellow

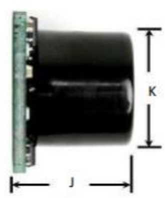


Fig 5. Data sheet for dimensions and specifications[4]

Fig 6. 4m long US sensor(detecting object sides of the bicycle)

Working Voltage	**DC 5 V**
Working Current	**15mA**
Working Frequency	**40Hz**
Max Range	**4m**
Min Range	**2cm**
MeasuringAngle	**15 degree**
Trigger Input Signal	**10uS TTL pulse**
Echo Output Signal	**Input TTL lever signal and the range in proportion**
Dimension	**45*20*15mm**

Fig 7. Datasheet for another US sensor[5]

2.4 Block Requirements

Module	Requirements
Vibration Motor	● Vibration motors' power supply is: 1V-9V, 0.08A current, with 10% error**. ● The dimension of the motor must fit in the Attachable Haptic Feedback, therefore, it cannot be very large. To feel the vibration of the motor, we are likely to use the ERM motor or flat motor used in smartphones.
Attachable Haptic Feedback Power Source	● Power supply voltage: 5V+/- 10% error
Receiver	● Can always receive coherent signal from the bluetooth module and send signal to the Three motors and let them vibrate. ● Detect bluetooth signals within 50cm.
Bluetooth Module	● Can always send coherent and correct signal to the receiver. ● Bluetooth modules' power supply: 3V-6V+/-10% error
Ultrasonic Sensor	● Can detect objects from 0.5-6.5m. ● Dimensions: 40mm x 20mm x 10mm (as long as it can fit in the detector case).
Detector Case Power Supply	● Power supply voltage: 5V+/-10% error

Fig 8. Block Requirements

** We take into account % error because the specifications of the Voltage and current for parts we buy will never be exact, thus we take into account a 10% error which is the standard we aim to have for our parts so that the final product can be successful. Anything out of the 10% error range will need to be replaced.

2.5 Risk Analysis

The block or interface that poses the greatest risk to the successful completion of the project might be the connection from the bluetooth module to the Attachable Haptic Feedback. While the speed of sound is fast, it's not as fast as light. The different relative speed between

the bike and the object behind may affect the accuracy of the distance measurement. We will need to measure the error and determine whether the relative speed plays a critical role in our actual implementation.

Another aspect of the physical design we need to consider is the placement of the sensor. Different bikes have different structures, and a bad placement of the sensors may pick up the distance between the sensors and parts of the bike which will give constant reading and negate our purpose of detecting object around the bike.

3. Ethics and Safety

All of the parts that we use should be RoHS compliant[6] as all our parts will be purchased from well known manufacturers in the US with approved safety ratings in order to produce a high quality product with fast shipping. The electronics will be placed within a waterproof case that will also be purchased from ethical manufacturers, which will be of high quality and provide as much protection as possible from rain and also sweat from the bicyclist, thus protecting the user from electrical hazards.

We are mainly concerned with the electronics that are within the Attachable Haptic Feedback as the electronics that will be closest to the user will pose the greatest risk to the user's health and safety. Because of this, we will need to also need to have protective casing around the electronics as backup protection which will be reliant on the electronics shop as they will be able to produce a personalized case for our project.

The lithium ion batteries that we are using will also be a safety concern as they will become a hazard if not handled or used properly, especially in the conditions bicyclists will operate the product in. People who have skin contact with objects that are 48˚C for up to 5 minutes will sustain third degree burns[3]. Therefore, we aim to minimize user risk by designing a safe and sturdy product that will have sufficient circulation for the battery to cool down, and will also be waterproof in order to prevent electrical hazards from occurring.

The motors that we are using will be low power since they only need to be strong enough for the user to feel the vibrations they emit, and thus will not need high voltage batteries to operate, but the batteries will still injure the user if overloaded and not used properly.

According to the IEEE code of ethics[7]:

"We, the members of the IEEE, in recognition of the importance of our technologies in affecting the quality of life throughout the world, and in accepting a personal obligation to our profession, its members and the communities we serve, do hereby commit ourselves to the highest ethical and professional conduct and agree:

1. to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;
2. to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;
3. to be honest and realistic in stating claims or estimates based on available data;
4. to reject bribery in all its forms;
5. to improve the understanding of technology; its appropriate application, and potential consequences;
6. to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;
7. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;
8. to treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression;
9. to avoid injuring others, their property, reputation, or employment by false or malicious action;
10. to assist colleagues and co-workers in their professional development and to support them in following this code of ethics."

We pledge to follow all the guidelines of the IEEE code of ethics, and in our pursuit of greater understanding of technology and its potential impact on the world, we also understand its potentially harmful effects if technology is used to do wrong in the world. We will accept any honest criticism from the ECE faculty while we work on the ECE445 Senior Project in Fall 2017 and will aim to make our final product safe for human use.

References

[1] Cyclist and pedestrian crash statistics:

http://www.pedbikeinfo.org/data/factsheet_crash.cfm

[2] Bike accident statistics:

https://www.bikeaccidentlawyersblog.com/2017/04/02/nhtsa-bicycle-car-deaths-12-percent-one-year/

[3] Time Required for a third degree burn to occur:

http://chfs.ky.gov/NR/rdonlyres/2CFE26ED-59A5-4F60-91A7-E2B5C0E9D000/0/BurnsintheElderly091213.pdf

[4] Long range(6.5m) US sensor:

https://www.maxbotix.com/documents/LV-MaxSonar-EZ_Datasheet.pdf

[5] short range(4m) US sensor:

http://www.mouser.com/ds/2/813/HCSR04-1022824.pdf

[6] RoHS compliance guidelines

http://www.rohsguide.com/

[7] IEEE Code of ethics:

http://www.ieee.org/about/corporate/governance/p7-8.html