1. Introduction

1.1 Objective

The streets are a busy place, and it is impossible to be looking all around you at once. There could be a car approaching on your left while you are distracted by a flying newspaper. You could be so confident in your turns that you don't notice the trash bin right beside you. There are many dangers that exist on the open road, some coming at you directly and some unable to be moved by the impact of your bike.

Our solution to this problem is a belt with haptic feedback that will detect objects behind and to the side of you to give you a better idea of where the dangers are. This belt will vibrate when a car pulls up beside you or if you've stopped by a garbage can without noticing. The vibrations get stronger the closer the object is to give you a better idea of how imminent the dangers are. You no longer have to look around aimlessly trying to find every roadblock as this belt will tell you where they are.

1.2 Background

There has always been research into ways for cars and trucks to detect objects in their blind spots. While a biker has a wider field of view than a car, they still cannot be looking around them all the time for incoming obstacles. There are some systems available to detect objects around a bike but most require you to take your eyes off the road to look at a display. They are also upwards of $300 and not commercially available. Our device uses haptic feedback to tell you where an object is approaching and how close it is to you. It uses an extra sense that is not normally used when riding a bike to notify you of what is around you.

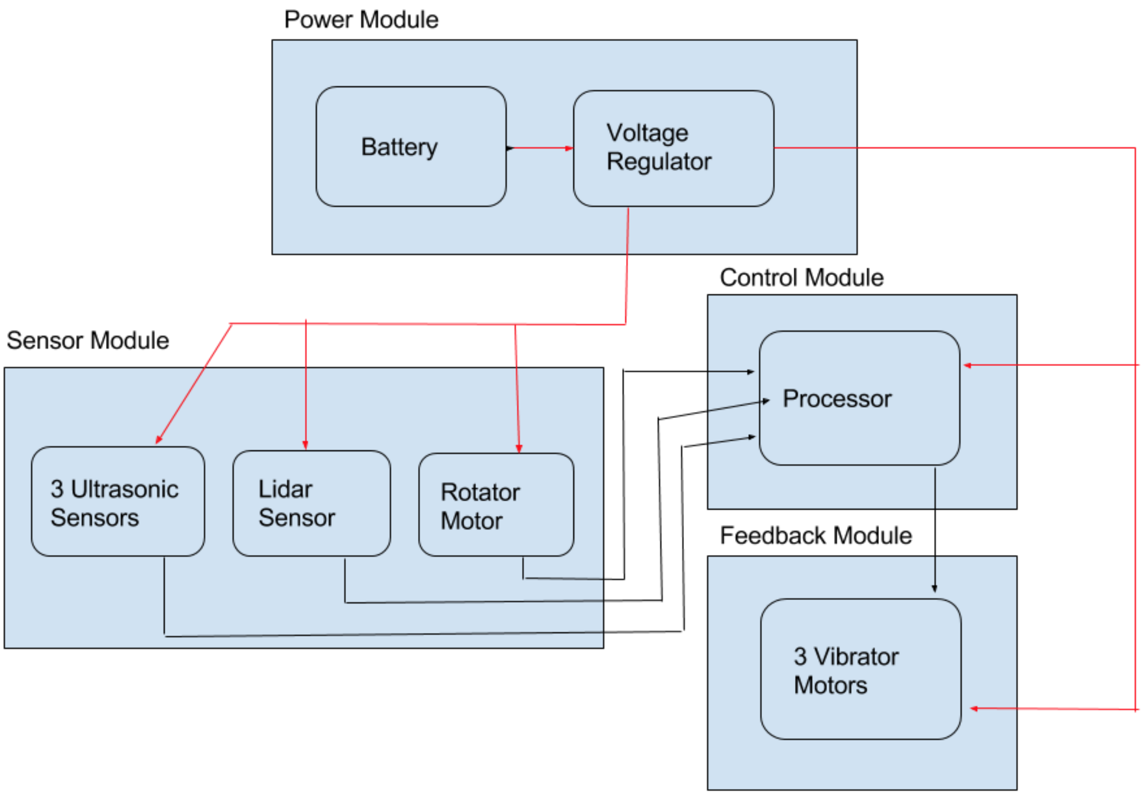
Most of these devices use radar or ultrasonic sensors to detect the objects that are approaching [2]. Our device will use a combination of lidar and ultrasonic sensors to detect incoming obstacles. Ultrasonic is mostly useful at close range, so we added a lidar sensor to be able to detect things farther than the ultrasonic can. The ultrasonic sensor will mostly be used to alert the wearer to objects in their immediate vicinity.

1.3 High-level requirements

- Detect objects from 1~12 m away and alert user based on distance
- Have range of 180 degrees when measuring objects close to the wearer
- Cost less than current commercially available radar sensor ($300)
- Run for at least 4 hours on a single charge

2. Design

2.1 Block diagram



--- Data
--- Power

2.2 Power Module

The power module is tasked with supplying power to all components in the device. There are three ultrasonic sensors, one lidar sensor, one rotating motor, three vibrating motors, and one microprocessor that need power. The module consists of the battery and a voltage regulator. The battery holds the charge to be used later and needs to last more than four hours on a single charge. The voltage regulator needs to be able to modulate the voltage to the level the parts need, within their operating requirements, once the components are all picked.

2.2.1 Battery

Since we need a power source that is both easily accessible and rechargeable, we settled on using a lithium ion battery. The battery of the device will be a standard 12 V lithium-ion battery. The battery needs to hold enough power to supply it to all the other components of the device. The parts needing power are the ultrasonic sensor, lidar sensor, rotating motor, microprocessor, and vibrating motor.

The battery will be connected through a wire to the voltage regulator and exist as a free hanging object. The device can be stored in the wearer's pocket or secured to the belt in a pocket or attachment.

Requirement: This battery must be able to supply power for more than 4 hours.

2.2.2 Voltage Regulator

The voltage regulator needs to take the voltage from the battery and modulate it so that it can be used by the ultrasonic sensor, lidar sensor, rotating motor, microprocessor, and vibrating motor. The input voltage should be able to handle the operating ranges of the battery we choose and output a voltage that is within 5% of the required voltage of the other components.

Requirement: The voltage regulator must be able to supply the necessary voltage to all the sensors and motors.

2.3 Sensor Module

The sensor module will be used to take information from the environment and feed it into the microcontroller. It will use lidar sensors and ultrasonic sensors. It should be able to reasonably sense if there is and object within 12 meters and become very accurate within 4.5 meters.

2.3.1 Lidar Sensor

The sensor that we will use is the Benewake TFMINI Micro LIDAR Module [4]. This sensor is affordable and accurate up to 12 meters and is also accurate at biking speeds. This sensor will be on a motor so that it can turn 140 degrees to detect things behind the wearer.

Requirement: This sensor must be able to accurately sense the distance up to 12 meters with an accuracy of 10 centimeters.

2.3.2 Ultrasonic Sensor

The ultrasonic sensors that we will use are the HC-SR04 Ultrasonic Distance Sensor Modules [5]. These sensors are cheap and accurate up to 4.5 meters. There will be three of these sensors that will be on the left, right, and center of the back of the wearer. The purpose of these sensors is to give more accurate feedback at shorter ranges.

Requirement: This sensor must be able sense the distance up to 4.5 meters with an accuracy of 5 centimeters.

2.3.3 Sweeping Motor

The sweeping motor will be attached to the lidar sensor and must rotate back and forth across a 140 degree range behind the belt. The motor needs to be able to send data containing the current angle the lidar is facing.

Requirements: The motor must be able to take up to a 12 V input, to be determined based on what kind of motor we pick.

2.4 Control Module

The control module will need to take inputs from the both the lidar sensor and the ultrasonic sensors. It will also take an input from the lidar motor to sense what direction the lidar is facing. The output will tell which of the vibrating motors to start vibrating, and how intensely.

2.4.1 Microcontroller

The microcontroller has not been decided yet, but it will need to be programmable so that we can test to find the optimal amount of vibration for different distances.

Requirement 1: The microcontroller must be able to turn the vibrating motors on and control the vibration.

Requirement 2: The microcontroller must be able to handle the inputs from the sensors.

2.5 Feedback Module

The feedback module consists of a collection of three vibrating motors. The motors will be located at the left, right, and back side of the belt. The motors need to be able to vibrate at different intensities to signal how close an object is to the wearer. The motors will be supplied power from the battery and voltage regulator, and the control module should dictate when and how strong each of the motors will vibrate.

Requirement 1: The haptic feedback motor must be able to alert the person 19 times out of 20.

Requirement 2: The motor must take an input of up to 12 V, to be determined based on what kind of motor we pick.

2.6 Functional overview

The device needs to take the data from the sensors and rotating motor and give it to the microprocessor. The microprocessor will tell the vibrating motor when to vibrate and how strong to. Motors should increase in strength when the sensors detect that an object gets closer.

Risk analysis

The lidar sensor is one of the most important parts of this project, and it could possibly have some problems. The website says that it works in all types of light environments [4], but it could work differently outside. Also, there comes some risk involved with the way we are using this sensor. We want it to sweep back and forth to cover an area behind the wearer, but that could make the laser pick up some unwanted detections.

Another risk to the project is the way that the belt works, a simple belt may not have enough support to carry the entire device with all of its sensors and batteries. The belt will also not always be facing exactly where we want during different activities such as running or biking. To counter this problem, we will make something that the lidar detector can hinge on with the bottom of the detector being more heavily weighted. This should cause the lidar sensor to face the way that we want, which is even with the surface of the earth.

Ethics and safety

Lithium ion batteries are known to malfunction when overcharged or at high temperatures [1]. Most of these issues can be avoided as the batteries usually come with overcharging protection. We must also consider how the battery is stored. The battery needs to be held on the person's body either in a pocket or attached to the belt.

Since we are using vibrating motors to alert the wearer where the dangers are coming from, the motors must be strong enough to alert the person but not enough to shock the person. Shock meaning both electrical shock and scaring the person that is wearing the device. We also cannot have a super strong motor that is constantly running while a person is right next to an object.

An important thing to note is that while this device will alert someone to the dangers around them they still need to be aware of their surroundings. A person cannot solely use this device to navigate around. This is not a replacement to looking around but an assistance device.

Something else to consider is the device will be worn outside the person. The person will most likely be biking outside so the device needs to have some sort of weatherproofing. We are considering wrapping all exposed connections.

We want to make sure the device is safe to use, which is why we are going through all these safety requirements.

References

[1] **http://batteryuniversity.com/learn/archive/lithium_ion_safety_concerns**

[2] **https://www.dcrainmaker.com/2014/07/hands-on-backtracker-radar.html**

[3]https://www.wavetronix.com/en/case_studies/13-bicycle-detection

[4]https://www.robotshop.com/en/benewake-tfmini-micro-lidar-module-12-m.html?gclid=EAIaIQobChMI1pz9spmV2QIVBodpCh0xIQizEAQYBSABEgKPOvD_BwE

[5]https://www.bananarobotics.com/shop/HC-SR04-Ultrasonic-Distance-Sensor?gclid=EAIaIQobChMI4eLL3J6V2QIVUJ7ACh0OUABFEAQYASABEgLNZvD_BwE

[6]https://www.ieee.org/about/corporate/governance/p7-8.html