AUTONOMOUS POTHOLE DETECTION AND CATALOGING FOR BIKES

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ECE 445 Project Proposal Spring 2018
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1 Introduction

1.1 Objective

Potholes are an issue which plague cities all around the world. While damaging to cars, potholes are particularly dangerous, even fatal, for bikers and can lead to millions of dollars in lawsuits for a city if not patched [1]. Bikers need to be very aware of the surroundings around them while on the road, but with so much going on, it can be easy to miss potholes, both at day and at night. However, for cities to be able to fix potholes, they need to first know where they are. Currently, the city of Champaign is starting to utilize a phone application for reporting problems like potholes, but few bikers are going to stop, get off their bikes, and pull out their phone to fill in a report [2]. Most cities simply utilize a telephone number or website for pothole reporting, which is even more inconvenient.

Our project aims to ease the issues of both pothole cataloging for municipalities as well as pothole warning for bikers. We aim to do this by creating a device which can detect potholes via computer vision (for long-range detection) as well as accelerometers (for potholes actually hit). In addition, a user can report a pothole they ride past by pressing a button. Once a pothole is detected by the system, the device’s current GPS location and time is sent to a database for municipalities to access. Devices will also host a local copy of this database, which will be used to warn bikers via haptic feedback if they are riding towards an area with many potholes. In addition, when the computer vision portion detects a pothole, the rider will also be alerted, in case they didn't spot it themselves.

1.2 Background

Research papers have been written about pothole cataloging techniques, but commercial products have been few and far between. In addition, all research papers that we found focused upon the use case for cars. There was one commercial product which advertised obstacle warning for bikes, but its crowdfunding campaign ultimately failed [3]. Generally, these papers describe specific parts of a pothole detection system, such as computer vision techniques [4], laser imaging techniques [5], or accelerometer-based techniques [6]. The high cost of laser-imaging techniques makes them impractical and computer-vision based techniques suffer from mediocre accuracy and false positives. No systems that we found combine these techniques. In addition, these papers generally fail to describe any type of pothole warning system, which we believe would be useful for both drivers and bikers.

By combining various aspects of these techniques, we hope to create a holistic system which will enable quick, easy pothole cataloging while also warning the biker of nearby potholes in order to prevent accidents.

1.3 High-level requirements list

- Device must identify potholes with at least 80% accuracy
- Pothole identification must take no longer than 5 seconds
- Device must be able to grab and send location data upon pothole detection
- Device must be able to warn user of nearby potholes using database and current location info

2 Design

Our design consists of 3 main blocks, a power module, a control/feedback module, and a computer vision modules. The power module supplies power to the other modules and ensures they can run for the duration of the bike ride. The control/feedback module tracks the current location of the device, transmits the location of detected potholes, analyzes motion data to do pothole detection, and offers haptic feedback when the rider encounters an area with potholes. The computer vision module detects potholes visually.

Block Diagram

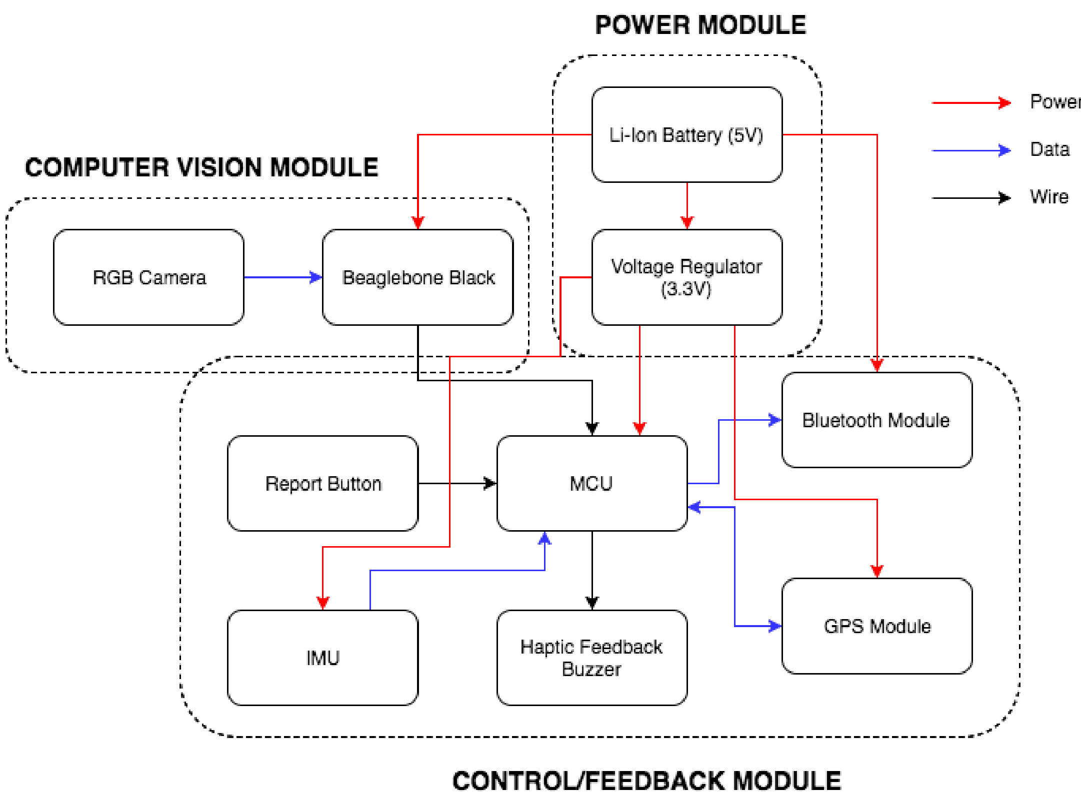

Figure 1: Block Diagram

2.1 Power

Description

As this will be a mobile product, we will require a mobile power source. We plan on utilizing a rechargeable USB power bank which operates at 5V. This will also feed into a voltage regulator for any modules which operate at 3.3V.

2.1.1 Li-Ion Battery

Functional Overview

The battery supplies mobile power for our project.

Requirements

- Capacity > 5000 mAh
- Interfaces through USB connector
- Rechargable

2.1.2 Voltage Regulator

Functional Overview

The voltage regulator maintains a constant voltage for smooth operation of our device.

Requirements

- Provide 3.3V +/- 5% output from 4.7V - 5.3 V source at 1 A

2.2 Control/Feedback Unit

Description

The control/feedback unit takes care of processing pothole detection events, recording and sending their location, as well as alerting the user if their GPS location is near a pothole or if the computer vision module detects a pothole.The GPS, IMU, MCU and bluetooth module will communicate via an I2C bus.

2.2.1 MCU

Functional Overview

The MCU takes care of polling/processing the IMU data in order to detect potholes, as well as processing pothole detection events from the report button and computer vision module. It takes care of the pothole reporting mechanism when a pothole is detected in addition to determining if a user is approaching a pothole and warning them appropriately.

Requirements

- Solderable package

- Must be able to communicate over I2C in at least standard mode (100 kb/s)

2.2.2 Button

Functional Overview

The button provides a method for a user to easily report a pothole if it is missed by both the computer vision module and IMU.

Requirements

- The button's length and width should be between 0.5 - 2 in.
- It should be easily pressable

2.2.3 Bluetooth Module

Functional Overview

The bluetooth module allows our device to connect to a phone in order to send pothole locations to a remote database.

Requirements

- Minimum range 2m
- Must be v4.1+ to take advantage of low power mode

2.2.4 GPS Module

Functional Overview

The GPS module will be used to determine the user's current location in relation to nearby potholes as well as the locations of potholes detected by the system.

Requirements

- Include a patch antenna
- Cold start TTTF < 60 s

2.2.5 IMU

Functional Overview

The IMU allows for detection of potholes that the user runs over. We will likely only need the accelerometer for this. Requirements have been chosen from the following paper [7].

Requirements

- The accelerometer must have at least 2G range.
- Must have at least a 100 Hz sampling rate
- Must communicate over I2C

2.2.6 Piezo Buzzer

Functional Overview

The buzzer serves as a method of warning the user of incoming potholes.

Requirements

- > 60 dBA

2.3 Computer Vision Unit

Description

The computer vision unit analyzes visual data to detect potholes and communicates that information to the main microcontroller. This unit detects potholes before they are hit, in contrast to the IMU.

2.3.1 RGB Sensor

Functional Overview

Our camera will capture image data for pothole detection and send it to the the detection MCU for processing.

Requirements:

- Minimum capture rate of 10 frames/second for data input every 2 ft. at 12 mph
- 360p resolution

2.3.2 Detection Microcontroller

We will use a dedicated microcontroller for image processing to ensure it can be completed as rapidly as possible. The detection microcontroller will notify the main control microcontroller whenever a pothole is detected.

Functional Overview

Requirements

- Minimum 1 GHz Processing speed to output data every 10 ± 2 ms
- Minimum 128 MB of memory

2.4 Risk Analysis

We believe the computer vision block presents the biggest risk of failure for our project. Speed is a significant issue as image processing tasks can be computationally intensive. We will need to carefully select suitable hardware and write our algorithms to be as efficient as possible.

The accuracy of the computer vision is also an area of concern. There are many unforeseen variables in the real world the can affect the performance of our unit. In addition we will also have to do a lot of testing to find the ideal parameters for our algorithm to respond to these conditions. Existing computer vision algorithms have only found success in broad, daylight conditions. In addition, these algorithms have been designed for pothole detection on automobiles, which would offer a smoother camera feed than on a bike.

3 Ethics and Safety

If we perfect our project to be able to do real time pothole detection with ample warning time, it may cause a sense of complacency in the user. They may become more prone to distraction if they believe they can completely rely on the system which is a dangerous situation.

Since our project is designed to be used outside, there is a chance it will be exposed to rain or other precipitation that could damage the components. To mitigate this, we will test our case to ensure it is at least IP13 compliant.

In the case of potential shorts we will design the circuit in a way that if the current is too high we will cut off the battery. This would be the most effective way to protect the user and the parts.

The continuous recording of the road could mean that people who do not want to be recorded can be in public. This could cause an ethical issue, however we believe that this device can be compared to dashcams. Our device will also be continuously deleting video as its been processed.

References

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