Bike Crash Detection

Team 24 - Brian Lin, Dhruv Mathur, and Alex Tam

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TA: Kristina Miller

1 Introduction

1.1 Objective

Biking has become a vital means of transportation. 12.4% of Americans cycle on a regular basis or about 47.5 million Americans a year (statista.com). There were 467,000 reported accidents involving bicycles in 2015 [3]. 2.1% of all traffic related deaths were pedalcyclist fatalities in 2017 [4]. There have been many expensive and inexpensive innovations to increase communication between cyclists and motor vehicles such as the Varia Rearview Radar ($200) [2] and the Zackees Turn-Signal Gloves ($60) [7], but the overall deaths per year in motor vehicle accidents involving pedal cyclists continues to increase [4]. 82% of all motor vehicle vs pedalcyclist deaths involved the front of a vehicle [4] indicating that visibility is not the main issue in the crash. From 2000 to 2013 commuting rates increased 105% [5]. In these situations, it is rare for cyclists to ride in groups. Group riding not only makes the cycler more visible, it also allows for the rider to gain help immediately. This is not an option for the majority of riders, a device to communicate with emergency contacts in the event of a crash would be beneficial. Cyclists lack the safety innovations that many modern cars benefit from such as the OnStar safety and notification system. There are devices for the bicycles that detect crashes such as one of the most inexpensive options the Garmin Edge 530 for $300 [8]. However, there is no solo inexpensive device that offers these capabilities without the expensive overhead of active GPS for navigation and hardware to communicate with bike sensors such as power meters. Our device caters directly to commuters who have no need for expensive hardware to measure performance.

Our goal is to develop a device that can allow cyclists to have access to the critical care immediately after the accident. It would be beneficial for many bikers to have a device that can detect when they are involved in a crash, and notify an emergency contact via text message of the severity of the crash so that the rider can get assistance. Many current solutions rely on the helmet design, but only 17% of all cycling fatalities involved a helmet [6]. A no hassle solution that is guaranteed to stay on the bike will ensure that the device is present when an accident inevitably occurs.

1.2 Background

Right now there are no low-cost, attached to bike solutions for accident detection and handling. Devices on the market are traditionally attached to the helmet. However most cyclists do not use a helmet making it impractical to have an accident detection device on the helmet. Attaching the device to the bicycle ensures that the device will be there when need be. Furthermore, to ensure that as many cyclists have access to it, we want to implement a cheap and durable option. A helmet solution costs $50 or more [1] making it impractical to purchase for most consumers.

1.3 High-Level Requirements

- The device must accurately detect a crash and distinguish crashes from dropping the bike or sudden controlled stops.
- The device must quickly send a message to emergency contact(s) with relevant information after an accident, specifically the time, location, and severity of the crash.
- The device must be durable enough to survive crashes and should be low-cost (<$30).

2 Design

2.1 Block Diagram

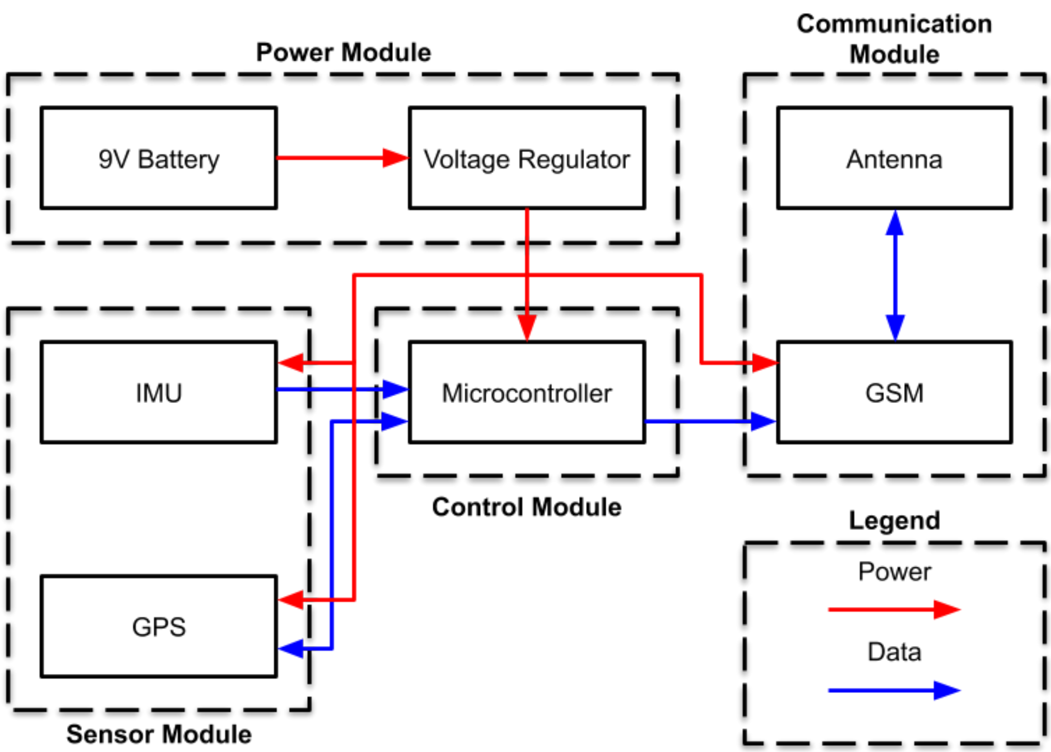

Figure 1: Block Diagram

The device has four main modules: Power, Control, Sensor, and Communication. The Power Module contains the power supply, coming from a battery, and voltage regulators to provide clean 5V and 3.3V supplies to the various chips. The Control Module consists solely of the microcontroller, which interfaces with the sensors and communication module. The Sensor Module consists of the IMU and GPS chips, which are used by the microcontroller to detect crashes and location. The Communication Module contains the GSM chip and antenna that will be used to connect to a cellular network in order to send text messages.

2.2 Functional Overview and Block Requirements

2.2.1 9V Battery

The main power source will be a 9V battery. This will provide power to the microcontroller, IMU, GPS, and GSM chips and will be easily accessible to the user for replacement when the battery dies.

Requirement: Must provide ≥500mA between 7V-10V for the Voltage Regulators.

2.2.2 Voltage Regulators

There will be two voltage regulators, one to convert from the 9V supply to 5V, and one to convert the 5V supply to 3.3V. The 5V supply will power the microcontroller, GPS, and GSM chips. The 3.3V will power the IMU chip.

Requirement 1: The 5V regulator must provide ≥400mA between 4.5V-5.5V.
Requirement 2: The 3.3V regulator must provide ≥100mA between 3V-3.6V.

2.2.3 Microcontroller

The microcontroller will be an ATmega2560, and will be used to process the IMU data, communicate with the GPS chip, and control the GSM chip using three parallel serial connections. The microcontroller will be responsible for identifying a crash using the IMU data, parsing the location from the GPS data, and controlling the GSM to send a text with the relevant information.

Requirement: Must communicate over three hardware serial ports simultaneously.

2.2.4 IMU

The IMU will be an ICM-20689 chip, that contains a 3-axis accelerometer and a 3-axis gyroscope. Both have programmable limits that will be tuned as needed to accurately detect crashes. According to Stone and Broughton, fatalities on bicycles increases from 3% to 10% when vehicle speeds 30mph to 50mph [10]. This speed coreleates to 14g of acceleration in a normal crash with an average adult male. [11]

Requirement: Must accurately report accelerations under 14g and rotations under 500dps.

2.2.5 GPS

The GPS will be a NEO-6M GPS Module, that can communicate over a serial interface with the microcontroller to report the location of the device when a crash occurs. The chip will not always be active in order to reduce power consumption.

Requirement: Must provide parsable GPS data within a 10m radius of the device [12].

2.2.6 GSM and Antenna

The GSM will be a SIM800L module, which will receive data from the microcontroller on when to send a text message. The GSM module will communicate with the antenna to send the message over a cellular network.

Requirement: Must connect to a cellular network and reliably send text messages 99% of the time in an urban or suburban environment, accounting for cellular service reception.

2.3 Risk Analysis

The block that poses the greatest risk to successful completion is the GSM and Antenna module. It is reportedly difficult to work with and requires detailed configuration to become operational. It also requires a SIM card to connect to a cellular network that must be provided by the project team.

3 Safety and Ethics

Our device will be used exclusively outdoors so it must be able to deal with the elements. The protective case for our circuit will be IP54 rated. This means the case will have partial protection from dust and protected from water splashes from all angles.

As our device will be transmitting data to external sources, we must respect privacy as stated in the ACM Code of Ethics [9]. This means that we must only collect the minimum amount of information to make our device work. Our device will require a name, emergency contacts, and current location.

Lastly, we should “be honest and realistic in stating claims or estimates based on available data”. As we are detecting data from our gyroscope and accelerometer, we need to provide accurate guidelines and limits for crash detection. Therefore we must find the threshold in our data set that distinguishes between a crash and normal usage of the bike. This device does not replace a rider’s responsibility to contact the necessary people if need be.

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