Bicycle Crash Detector

Team 68-Qihao Wang, Jiayi Wu, Ruofan Hu
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TA: Chi Zhang

1 Introduction

1.1 Objective:

Bicycles are one of the most popular vehicles in the world because of its low price and convenience. Moreover, recently, bicycle-sharing system has become popular in lots of cities. With more people using bicycles as their primary vehicles, people also start to pay attention to the safety issue around bicycles. Based on the data from the U.S department of transportation, 854 cyclists have died across the U.S and each year, around 55,000 cyclists are injured in the U.S. Therefore, it is necessary to design a safety insurance system to provide extra help to cyclists when they are seriously injured. Our goal is to design a bike crash system with functionality of collision detection, automatic report crashes to policemen and alarm. The system is designed to protect cyclists when they can not call for help because of deadly injury including loss of consciousness and loss of hand functionality. The system will automatically send the crash location along with default messages to the policemen and contact selected by the user. Moreover, the alarm system will make sound and light signals so that the nearby people will notice the crash.

1.2 Background:

The previous solution uses the combination of a spike in acceleration in one or more directions with a rapid rotation in the bike's orientation to detect crash. It can detect crashes in most cases but might generate false alarms when riders ride downhill on rugged mountain roads. In this scenario, riders often turn the direction rapidly and brake sharly in order to keep balance and slow down, but the original solution might recognize it as a crash. In our solution, we add an alarm subsystem to which generate buzzer sound to inform people nearby. Besides, we can cancel the alarm if we think we can deal with the crash by ourselves or this is a false alarm. There are products in the market to detect the crash, but they do have alarm systems and require users to wear helmets and have to cooperate with APP.

1.3 High-Level Requirement

- The system will be able to detect a crash and prevent false alarm from other controlled cases with accuracy higher than 90%
- The system will be able to send a message to emergency contact(s) with a GPS location along with the default message written by the user. The deviation of GPS location should lower than or equal 5m radius.
- The solar power system can store enough charge for the system to work for 14 hours with no sunlight.

2.Design

1. Block Diagram

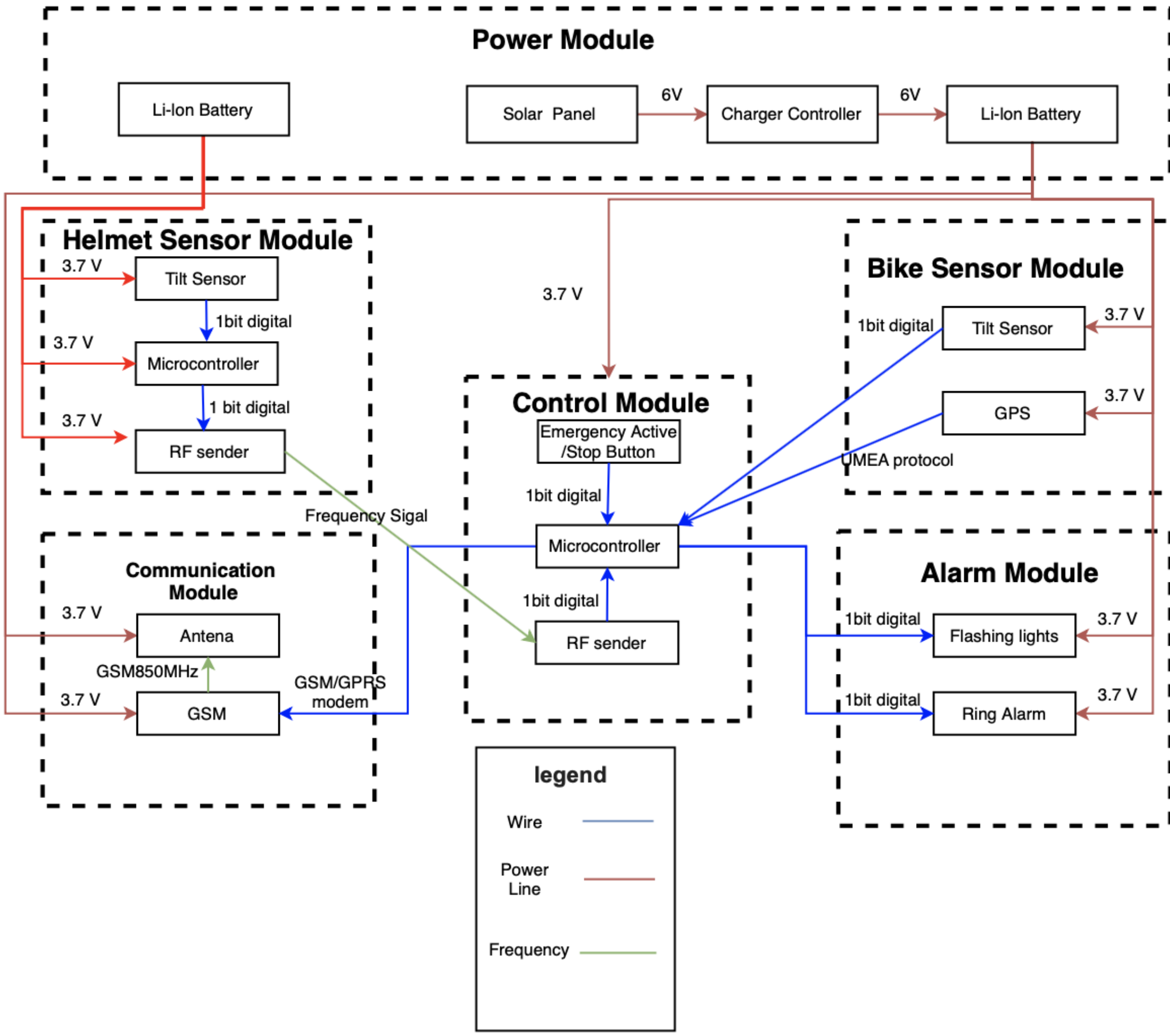

Figure 2.1 Block Diagram

2.Physical Diagram:

Figure 2.2 Side View[7][8]

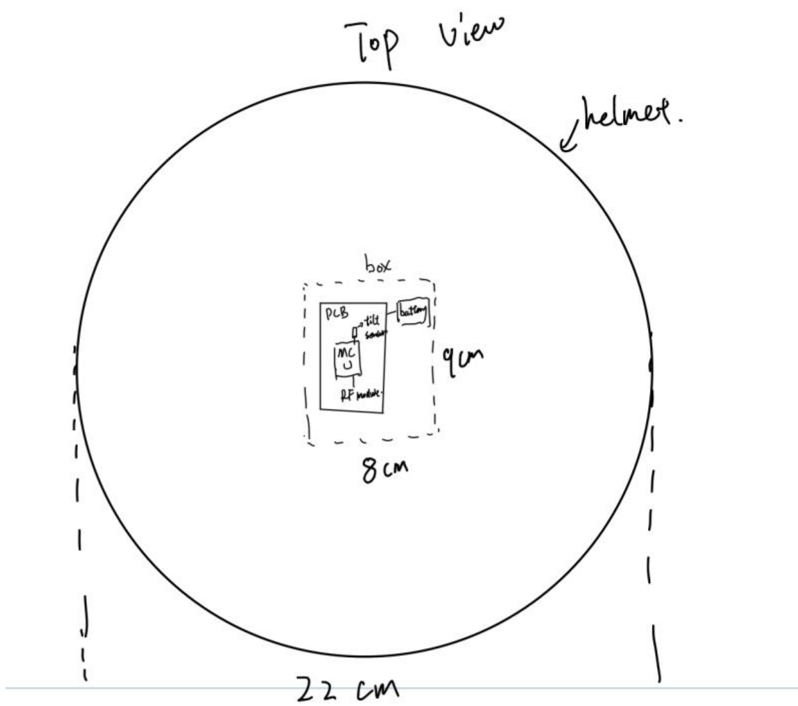

Figure 2.3 Top View

3. Block Descriptions

3.1 Power Module

A Power module will provide energy to the system so that the other module in the system can function normally. A Li-ion battery will be charged by the solar panel. Then the power output will be regulated to 3.7 V for the rest of the system.

3.1.1 Solar Panel

The solar panel will be the primary power source for the system. Its energy will be stored in a Li-ion battery.

Requirement	***Verification***
1.The panel can provide up to 1W, at 6 V and 180mA.	1. Step 1: we build a simple open-circuit measurer with a voltmeter. And in series connect a current meter to the power circuit Step 2: Measure the open-circuit voltage with a voltmeter, ensuring that the voltage 6V +/- 10%. And current is 180mA +/- 10% under normal sunlight

*2.*We require that the solar panel charge the battery 1000mAh fully in under 7 hours of sunlight.	2. Step 1: We put power system under sunlight for 7 hours Step 2: We again use the simple circuit open-circuit voltage with a voltmeter to measure the output of the Li-ion battery to see if we have it fully charged.

3.1.2 Charger Controller

The charge controller component will control the flow of the charge between the solar panel and the Li-ion battery. It monitors the status of Li-ion and once the battery is full it stops charging.

Requirement	***Verification***
1. The charger controller will allow current pass through to the battery until it is full and then stop charging.	1. Step 1: we build a simple open-circuit measurer with a voltmeter. And in series connect a current meter to the power circuit. Step 2: Measure the open-circuit voltage with a voltmeter, ensuring that the voltage 6V +/- 10%. And current is 180mA +/- 10% when the battery is not fully charged Step3: Once the battery is fully charged. We should not see current pass through from the the solar panel to charge controller

3.1.3 Li-ion battery

The lithium-ion battery will store the necessary power for the system.

Requirement	***Verification***
1. The battery must be able to store enough charge to provide at least 150mA at 3.6 V for 10 hours with no sunlight.	1. Step 1: we build a simple open-circuit measurer with a voltmeter. And in series connect a current meter to the power circuit. Step 2: Measure the open-circuit voltage with a voltmeter, ensuring that the voltage 6V +/- 10%. And current is 180mA +/- 10% when the battery is not fully charged Step 3: Once the battery is fully charged. We should not see current pass through from the the solar panel to charge controller

3.2 Sensor Module

We use the tilt Sensor and GPS for our sensor module. The tilt sensor is mainly used to detect the crash and the GPS sensor is used to send our location to our communication module.

3.2.1 Tilt Sensor

We use tilt sensors for our sensor module. In our design, we put the tilt sensor on the side of the bike and the top of the helmet to increase the accuracy. When the sensor inclines for more than 45 degrees, it will generate a ‘high’ signal [6] to the microcontroller and send the impact signal to the control module through RF transmitter. The sensor module is small enough so that it will not affect the rider.

Requirement	***Verification***
1.Tilt Sensor should be able to send the ‘on state signal’ (voltage low signal)	1. Step 1: We build a simple open-circuit measurer with a voltmeter. Step 2: Measure the open-circuit voltage when the sensor is tilted more than 45 degree. We should have a low voltage signal.
2. The debounce code should help the Tilt Sensor to distinguish the false described previously and detect the actual crash with accuracy higher than 90%	2. Step 1: We simulate all the false cases including turning, brake suddenly and small angle tilt. Each case for 10 times. And we will record all voltage signals. Step 2: We calculate our accuracy by Accuracy = False Number/Total Test Number

3.2.2 GPS

The GPS component can separate our system from the user phone, since the phone may be unreliable in lots of cases including damage, power-off, or loss. We plan to use the SIM28ML GPS module.

Requirement	***Verification***
1.Must provide parsable GPS data within a 10m radius of the device.	1. Step 1: We connect the GPS to the microcontroller so that we can record all the GPS data. Step 2: We will move around in two popular environments including normal campus environments such as green street and park environment which the users will encounter lots of obstacles. Moreover, we also like to test the GPS when we stay still Step3: we will plot the GPS data on the google map. And we can calculate the the difference between our GPS data and our actual location by formule Diff = SUM(ABS(GPS DATA - ACTUAL DATA))/Total data points If we have avg below 10m radius, our GPS is working properly

3.3 Control Module

The control module listens to the signal from the tilt sensors. When the controller module receives the impact signal from helmet and bike simultaneously, it will detect the crash and send an alarm signal to our alarm module.

Requirement	***Verification***
1.The microcontroller should be able to receive 1 bit signal from the tilt sensor and the digital GPS signal by UMEA protocol	1. Step1: Connect the GSM module and tilt sensor to the microcontroller and send the information. We tilt the sensor with angels 0, 60 ,90 degrees. And we print out all the signal received by the microcontroller Step2: we check if we get the right signal corresponding to the specific case. For example, the 60-degree tilt we should receive a voltage low signal. We also verified GPS information the same way as described in GPS module
*2.*The microcontroller will generate control signal and pass it to the alarm module	1. Step 1: we build a simple circuit using the LED to distinguish 0 and 1 signals. Step 2: We connect the circuit to the output pin of the microcontroller. And record the signal. Step 3: Verify if the signal is the same as our designed output.

3.The microcontroller will encode the GPS information and default message and pass it to the communication module	1. Step1: Connect the GSM module to the microcontroller and send the information. We would like to performance this experiment in different environment the same as described in GPS verification Step2: We calculate the success rate by success cases/ total tests We should get 90% to meet the requirement.

3.4 Communication module

Again, the GSM module is also a necessary component for our system to work correctly without a phone. The GSM module will connect to the antenna and send the default message along with the location provided by the GPS module written by the user to the police department and the user selected contact.

Requirement	***Verification***
1.The GSM should send the default message along with the location provided by the GPS module written by the user to selected contacts. The message should be sent successfully 90% when the service of the local phone network is available.	This function of this module will test together with the Control Module. Please read the Requirement 3 and verification of Control Module.

3.5 Alarm Module

In the GPS module, we stated that GPS will only provide parsable data within a 10m radius of the device. Therefore, we want to add these additional alarm devices so that the policemen or nearby people can quickly locate the crash location.

3.5.1 Ring Alarm

Similar to a car, the major purpose of the ring alarm is to make loud noise so that the nearby people will notice.

Requirement	***Verification***
1.The sound should be around 95 dB and should be clear within 10 m radius of the device.	Step1: Turn on the ring alarm module. And measure Decibel by Decibel Meter.

3.5.2 Flashing Light

Similar to a car, the major purpose of the flashing light is to provide visual aid to nearby people so that they can find the crash location fast and prevent a second crash.

Requirement	***Verification***
1.The light should be clear within 10 m radius of the device under normal condition and 5m radius if the weather is terrible.	1. Step1: Turn on the flashlight module. And we manually check if we can see clearly from 10m away.

3.6 RF Transmitter

The RF Transmitter will send the 4-bit signal to the Control System. In the Control System, RF receiver will catch the signal sent from the RF transmitter and decode the signal.

Requirement	*Verification*
1.RF Transmitter should be able to transmit 4 bits information wirelessly 2.RF Transmitter should be able to send with distance 1 - 3 wirelessly 3.The error rate of transition should lower than 10% 4.RF receiver should decode the information with an error rate lower than 10% 5. The input voltage for RF receiver and transmitter should be around 3.6v.	1. Step 1: we build a simple circuit using the LED to distinguish 0 and 1 signals. Step 2: We connect the circuit to the output pin of the RF receiver. And then we send 10 buttons and record the output on the RF receiver Step 3: Verify if the signal is the same as the 10 buttons, we pressed 2. The same steps as in 1. But we need to put the RF Transmitter 1-3 away from each other 3. We want to send 4bit/s and transit 1000 bits. And we calculate the error rate using the formula Bit Error Rate = Total Number of Bit in Error / Total Number of Bit Transition

	4. Measure the open-circuit voltage with a voltmeter, ensuring that it is sound be around 3.3V.

4. Circuit:

The following circuit shows how the sensor part communicates with our control module.

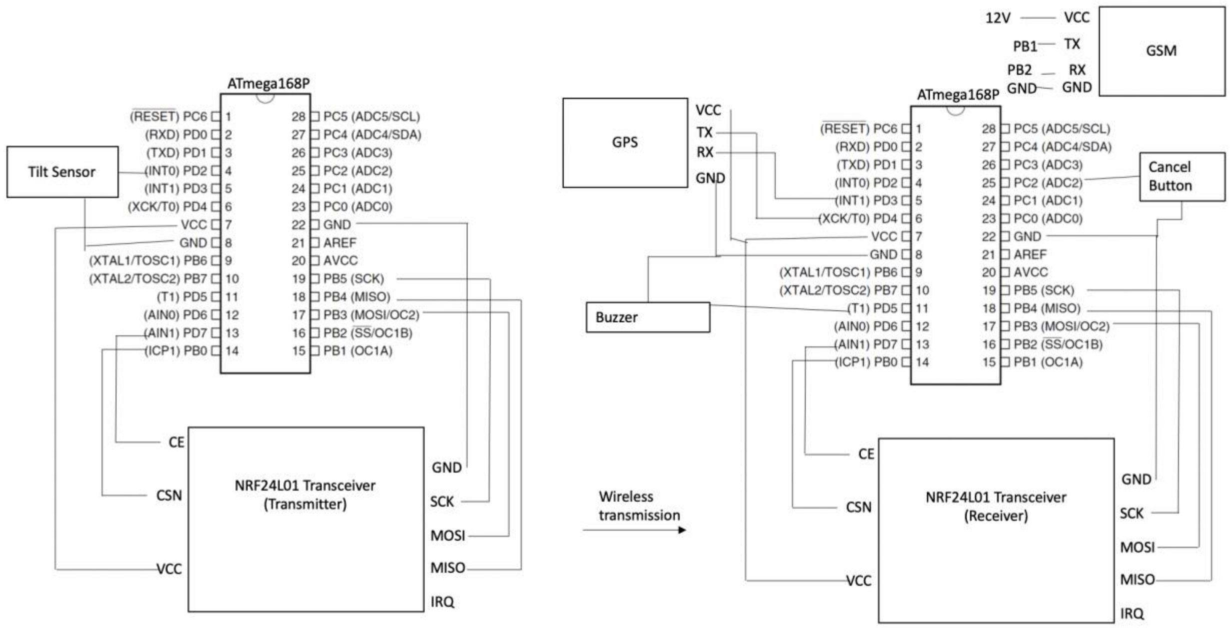

Figure 4.1 circuit

5.Debounce Code(essential parts):

The debounce code filters out the false cases by examining the total time of tilting. The comments in the code describe the function of every line.

```
// readSesnorData
int sesnorData = digitalRead(tiltSensor);

//false cases
if (sensorData != lastData) {

    //reset timer
    lastDebounceTime = millis();
}


//if the tilt time is longer than a false cases
if ((millis() - lastDebounceTime) > debounceDelay) {
    //.....case when tilt happen

    //activate GPS, GSM, ALARM MODULES

    //..........
}

//record the data value for next iteration
lastDatae = sensorData;

// delay to avoid overloading buffer
delay(100);
```

Figure 5.1 Debounce Code

6.Tolerance Analysis

The stability of the power system is very important for our system to function properly. We want to analyze our power consumption in sleep mode and activated mode. Sleep mode refers to the case which the driver is driving normally. Under sleep mode, only tilt sensors, GPS modules, and microcontrollers are consuming power. Activated mode refers to the case when a crash happened. Under activated mode, all modules are consuming power.

Sleep Mode:

GPS Module Current Consumption = 8 uA

ATmega88 Current Consumption = 1.8 mA

SIM Module Current Consumption = 6.0 uA

RF sender/Receiver Current Consumption = 18.0 mA

Tilt Sensors = 12 mA

Total Current Consumption = GPS Module + ATmega88 + SIM Module + RF Module

= 8 uA + 1.8 mA + 6.0 uA +18.0 mA +12 mA

= 31.814 mA

Activate Mode:

GPS Module Current Consumption = 16 mA

ATmega88 Current Consumption = 1.8 mA

SIM Module Current Consumption = 350 mA

Buzzer = 10 mA

LED = 20 mA

RF sender/Receiver Current Consumption = 18.0 mA

Tilt Sensors = 12 mA

Total Current Consumption = GPS Module + ATmega88 + SIM Module + RF Module

= 16 mA + 1.8 mA + 350 mA +18.0 mA +12 mA +10 mA + 20 mA

$$= \quad 417.8\ mA$$

Now if we assume that the system will work 13 hours under Sleep Mode and 1 hour under Activate Mode. We have

$$Combined\ Model\ Current\ Power\ Consumption = Activate\ Mode * 1\ hour + Sleep\ Mode * 13\ hours$$

$$Combined\ Model\ Current\ Power\ Consumption = \quad 417.8\ mA * 1\ hours + 31.814\ mA * 13\ hours$$
$$= 831.382\ mAH$$

Next thing, we want to fully charge our Li-ion batteries with 7 hours of sunlight.

$$battery\ charger\ current = Battery\ Capacity\ /\ Charging\ time$$

Formula 6.1

$$battery\ charger\ current = 1000mAH\ /\ 7H = 142.857142857\ mA$$

Therefore, in our project we choose a 180 mA solar panel and 1000mAH battery. In reality, the power will be lost during the transition of different components, so we choose our solar panel and battery larger than the result calculation. We believe that our power system should meet the high-level requirement in our project.

5 Difference

The solution for the crash detection system provided by the previous team is primarily to rely on the acceleration sensor. The previous team uses an acceleration sensor to detect a sudden acceleration speed and angle. However, this solution will likely have lots of false alarms. A sudden large acceleration of speed could happen if the driver tries to brake. And, a sudden large acceleration of angle speed may happen if the driver tries to turn around or just makes a large turn to avoid the crash. Here some data tolerance analysis from the previous team's design document.

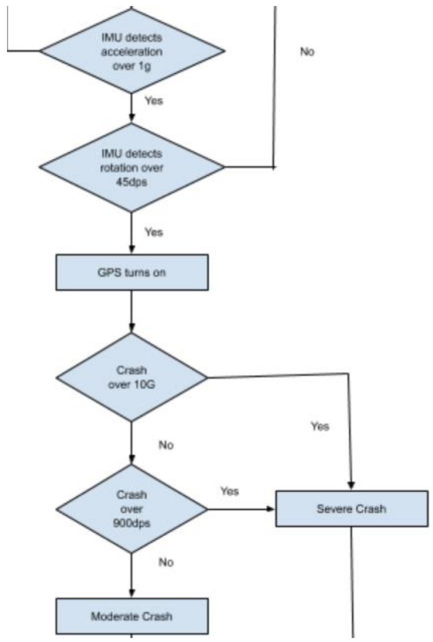

Figure 5.1 Flowchart from Previous Group's DD

Their standard data for detecting a crash is 1g acceleration. This number can easily be achieved by doing a braking. If we assume that a normal speed of a bike be 4.47 m/s (10mph). We can calculate the time need to stop to bike with 1g acceleration by using formula

$$T = V/g \qquad \textit{Formula 5.1}$$

$$T = V/g = 4.47 / 9.8 = 0.45s$$

It is very hard to find a model about the change of acceleration for bike braking, but it is reasonable to estimate a user will take 0.45s or less to stop a bike in normal cases. Therefore, the previous team system will likely be activated during even the normal cases.

In our solution, we are using the tilt sensor to measure the tilt angle of the bike with respect to the ground. Therefore, we will avoid all the false cases like brake and turn around. Moreover, we will provide the debounce code and an emergency stop button to avoid false cases like a large turn to avoid the crash. Here is a graph from the datasheet to show how the sensor works.

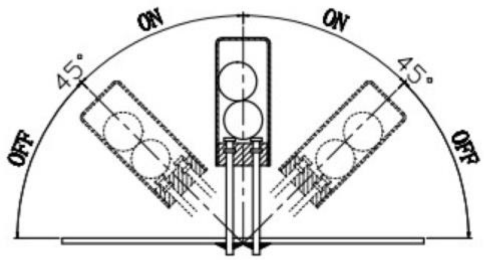

Figure 5.2 FlowChart from Previous Group's DD

Moreover, we will provide the debounce code to further avoid the false cases such as quick turning. The debounce code will analyze the total tilt time. The debounce code will filter out the case in which the bike only tilts more than 45 degrees for 1-5 seconds. These cases usually are caused by turning and minor vibration. In addition, even our system is activated because of false cases, we also provide an emergency stop button to allow the user to stop the system.

In the power aspect, the previous team uses a normal battery pack for all modules, which means the user has to switch the battery consistently. Otherwise, the user may not have enough power for the emergency cases. If we assume that users use bikes for 4 hours every day, the users will need to switch the battery every 25 days. Here is a direct quote from the previous team's design document:

> The battery has a capacity of 2500mAh. Current draw during normal activity without a crash is less than 20mA, as we only have to power the microcontroller and IMU. Therefore the battery should last at least 100 hours before requiring recharging.

Figure 5.3 direct quote from the previous team's design document

In our solution. we decide our system to use solar power so that the user does not need to worry about the power. We believe solar power is a reasonable choice for the bike since people would likely use the bike when the weather is good. The analysis about power in our system is described in the tolerance analysis section. In summary, our system will work 14 hours without sunlight and the battery can be charged in 7 hours under normal sunlight. Lastly, we also add a simple alarm module to help nearby people to locate the crash location.

In our solution, we adapt the GPS and SIM module from their solution. GPS module provides essential information for the police to locate the user. And with these two modules, the system can work without any dependency on the user's phone. Such independent functionality is crucial since we do not know the status of the phone when the crash happened. Lastly, we also add a simple alarm module to help nearby people to locate the crash location.

In conclusion, the solution provided by the previous team uses fewer components compared to our solution. Therefore, their solution is less cost in money, energy and size. And the acceleration sensor can provide the data with high accuracy such as angle speed and the moving speed. However, their solution will likely result in a high false rate in detecting. In our solution, we can detect the crash with high accuracy, and we use solar power to cover the power consumption. On the other hand, our solution costs more money, energy and size since we have more components.

6 Costs

Our fixed development costs are estimated to be $40/hour, 10 hours/week for three people.

$$\text{Labor Cost} = \frac{\$40}{hr} * \frac{10hr}{week} * 16weeks * 3 * 2.5 = \$48000$$

Our parts and manufacturing prototype costs are estimated as following:

Parts	quantity	cost	description	manufacturer
Small 6V 1W Solar Panel - Silver	1	$19.9	Primary Power source for the system	Adafruit
RECHARGEABLE 3.7V 1000mAH LI-ION BATTERY	1	$6.0	Primary Power storage for the system	Adafruit
USB / DC / Solar Lithium Ion/Polymer charger - v2	1	$17.5	Charger Controller	Adafruit
SIM28ML GPS module	1	$6.6	GPS module	SIMCom

ATmega168 microcontroller	1	$2.92	We will use the microcontroller to controller the system	Microchip Technology
GSM Module (SIM900A) With Antenna	1	$9.64	The RF receiver and RF sender, which is the necessary part for our remote controller	SIMCom
RED LED x 10	6	$9.5	Emergency Flasher for the alarm system	SparkFun
RS Pro by Allied 6173097	1	$2.9	Power Source	Allied
Tilt Sensor - AT407	2	$3.9	Tilt Sensor	LIGHT COUNTRY
receiver/transmitter NRF24L01	2	$4.2	The RF receiver and RF sender, which is the necessary part for our remote controller	Nordic Semiconductor
PCBs	2	No Cost	Our design of PCB should be 2 layers, the website says it is not cost	ECE SHOP
Total		$78.86		

Our calculation of cost is based on the minimum price in the market at this time and we do not consider the shipping cost. Therefore, we would like to put a $20 possible extra cost to the total cost.

In conclusion our total cost is

$$\begin{aligned}\text{Total Cost} &= \text{Labor Cost} + \text{Parts Cost} + \text{Extra Cost} = 48000 + 78.86 + 20 \\ &= \$48098.86\end{aligned}$$

7 Schedule

Week	Jiayi Wu	Qihao Wang	Ruofan Hu
WEEK 1	Research about the background about Bike Crash detect system	Research about the possible design for a new bike crash detect system	Research about the possible design for a new bike crash detech system
WEEK 2	Finalize the high-level requirement for Crash Detech system project	Research about possible choices for the crash detect sensors	Design the solar power system
WEEK 3	Doing the tolerance analysis on the detect sensors system	Designing the prototype circuit for the crash detect sensors	Doing the tolerance analysis on the solar power system
WEEK 4	Writing the design part of Document Design.	Writing circuit part of the Document Design based on the DDC	Writing tolerance part of the Document Design based on the DDC
WEEK 5	Changing the design part of Document Design based on the DDC feedback. Start to order all necessary parts.	Changing circuit part of the Document Design based on the DDC feedback Start Design the PCB	Writing tolerance part of the Document Design based on the DDC Feedback Start Design the PCB

WEEK 6	Programming microcontroller so that it has the function to process the input information for other modules and output the control signal to other modules	Test the prototype circuit of crash detect sensors	Test the prototype circuit of solar system
WEEK 7	Test the prototype circuit of controller system, GPS and alarm system on the breadboard	Designing the PCB	Test the prototype circuit of solar power and tilt sensor system
WEEK 8	Combine all parts and do the Prototype machine version 1 test	Finish and order version 1 PCBs (Early Bird)	Combine all parts and do the Prototype machine version 1 test
WEEK 9	Adjust the microcontroller programming based on the result of machine version 1 test	Adjust the PCB design based on the Prototype machine version 1 test (Round 1)	Continue on the Prototype machine version 1 test with change of circuit on the breadboard.
WEEK 10	Combine all parts and do the Prototype machine version 2 test	Combine all parts and do the Prototype machine version 2 test	Combine all parts and do the Prototype machine version 2 test
WEEK 11	Running the verification of launch subsystem requirement	Adjust the PCB design based on the Prototype machine version 2 test (Round 2)	Running the verification of remote controller subsystem requirement
WEEK 12	Reserve 1 week for any delay of previous schedule	Reserve 1 week for any delay of previous schedule	Reserve 1 week for any delay of previous schedule

WEEK 13	Prepare mock demo	Prepare mock demo	Prepare mock demo
WEEK 14	Begin final report	Begin final report	Begin final report
WEEK 15	Prepare final presentation	Prepare final presentation	Prepare final presentation

Ethics and Safety

There are several safety and ethical issues involved in our system. The device itself is pretty harmless to users but may have negative impacts on the public and cause ethic issues.

The first potential risk is the lithium battery that our system uses to store the energy. If disposed improperly, lithium batteries can be very dangerous. Thus, we must prevent batteries from being exposed to dangerous conditions like overcharging by monitoring the temperature of the battery and warn our users of the potential hazards the batteries can do.

According to [5]IEEE code of ethics term No. 1, we must hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment; The functionality of our system involved alarming and automatic calling to the police office. So, it is crucial for us to maintain the accuracy of our systems to avoid false alarms to the police or the public which may jeopardize the public welfare and efficiency. Moreover, maintenance and tracking are important to our system because our system is likely to be implanted on shared bicycles which means there’s risk that it might get lost or stolen which will also affect the public welfare.

Citations and References

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Sound intensity level
https://opentextbc.ca/physicstestbook2/chapter/sound-intensity-and-sound-level/

Li-lon Battery Charger with Thermal Regulation in SOP-8 Data Sheet:

https://dlnmh9ip6v2uc.cloudfront.net/datasheets/Prototyping/TP4056.pdf

RF receiver/sender Data Sheet:

https://www.sparkfun.com/datasheets/Components/nRF24L01_prelim_prod_spec_1_2.pdf

Previous Team's Design Document:

https://courses.engr.illinois.edu/ece445/getfile.asp?id=16233