Instrumented Bikes Project

EE476C - Senior Capstone Project
Instrumented Bike Team 1

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Sponsor: NAU Assistant Professor - Chun-Hsing Jun Ho

1.0 Cover Letter

Dear Dr. Chun-Hsing Ho,

First of all, thank you so much for sponsoring our senior capstone project. The team is very excited to be working on this topic and be responsible for creating a working product for you at the end of it. We are committed to providing you with a finished product by the end of this assignment, just the way that you have requested.

We chose this project because this technology and project description really interested us. We have heard about similar projects working on automobiles and are excited about trying to expand on that idea to make it functional with bicycles. We believe that our combined skills will allow for a successful end result.

This report describes our project outline as we best understand it. The next page of this report shows the Table of Contents for easy navigation to the different sections. We have also included the Project Definition and Depiction section which is where you will find a summary of the current problem that we are trying to solve and basic needs and wants that you have addressed. The project depiction is a simple diagram that shows a visual example of how the whole system will work. Since we are not experts on every part of this project, we have started to do research to learn more about the topic. Our research is included below. Lastly, we have outlined all the requirements and specifications that you have requested and we have come up with.

Once again, thank you and we are excited to work with you this semester.

From,

Instrumented Bikes Team 1

Robert Briggs
Hongpan Wu
Hao Wang
Junting Chen

2.0 Table of Contents

3.0 Project Definition and Depiction

Bicycling has been shown to provide many benefits, including: environmental, social, health, economic and transport. It produces minimum fossil fuel emissions, is affordable to almost 80% of the world's population, is a source of exercise, reduces cost of travel and uses much less road space as compared to other modes of transport. However, there are also some problems associated with riding bikes.

First, hazards like going uphill or downhill may be nothing more than a minor irritation for a four-wheeled vehicle, but for cyclists they're a serious problem. Bikes are far more sensitive to the camber of the road and changes in shape, texture and road quality. Bike trail conditions can have problems due to erosion, construction, and landscape in general. We can reduce the effects of these problems with a bike instrument that can warn cyclists in advance about adverse road conditions such as extreme uphill or big dips and bumps.

In order to complete this, our client is asking us to develop a system that senses accelerometer changes and can then communicate with other riders that there may be a problem ahead. By implementing this communication system, riders will be able to adjust their path to make safer and more efficient travel.

Our tasks first include, developing a system that maps trail conditions and sends data to a nearby laptop computer. Then we will need to apply this same idea to be able to store data on a smartphone. Once these are working, we are asked to create a way to communicate the findings to other riders.

Our client is asking us to make an "instrumented bike" that makes bike riding a better, safer, and more enjoyable experience. *Figure 1* shows a general idea of how our system will work.

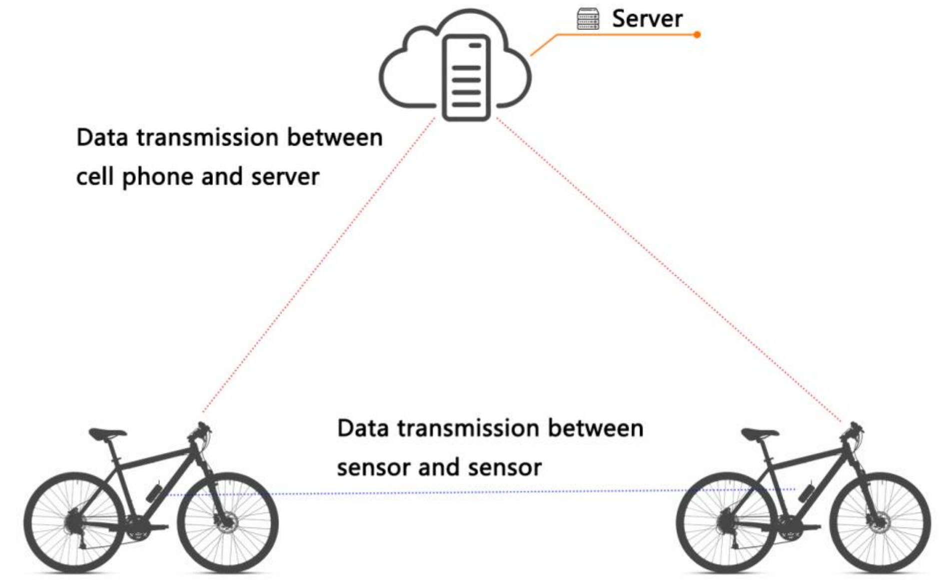

Figure 1: Project Depiction - shows a high-level overview of what our project intends to accomplish

4.0 Research

4.1 Current Limitations

We have learned that similar concepts to our project have already been implemented and designed. We will be using some of these findings as a foundation of our product. A graduate student at NAU that has developed this same device in automobiles. The graduate student (Matthew Snyder), is mapping local highway conditions using five accelerometers: four of them of the same brand as ours and one from a mobile phone. However, there have been a few limitations that we hope to develop further.

First, although data has been recorded for the road conditions, the accelerometers have not been properly calibrated. Although data has been read and recorded Matthew has had problems interpreting accelerometer readings. [1] However, for our project we have been provided with pre-calibrated accelerometers: SparkFun MMA8452Q. [2] We are still able to change the Zero-g offset in default settings if we desire. [2] These accelerometers are easily programmed with the Arduino microcontroller.

Second, the communication aspect of this project is in alpha stages in other applications. Matthew’s current highway data is only used for private use and has no aspect of communication between cars yet. [1] However, this technology is in early development (Land Rover and Tesla) and is very possible.

We are working to implement a way for these sensors to communicate with one another to alert riders when there are upcoming hazards. In order to alert the rider, we will need to store trail condition data on a server and then alert riders when they are close to that spot. This can be done using the GPS module that the client provided and an Arduino. We are not exactly sure how we will alert the rider because using smartphone notifications might be out of the scope of the project. This would require developing a mobile application. Once we have the working concept, it can be developed further by people with more time and resources. However, to display our concept it would be simpler to connect the GPS module and an LED to the Arduino so that we could turn the LED on when the rider is close. [3]

[1] M. Snyder, R. Briggs, E-mail. "Instrumented Bikes Project", 12 Oct-2017.
[2] U. Jimbo, "MMA8452Q Accelerometer Breakout Hookup Guide - learn.sparkfun.com", *Learn.sparkfun.com*, 2017. [Online]. Available: https://learn.sparkfun.com/tutorials/mma8452q-accelerometer-breakout-hookup-guide. [Accessed: 13- Oct- 2017].
[3]S. Monk, "Sparkfun Venus GPS and Arduino", Blog.
URL: http://www.doctormonk.com/2012/05/sparkfun-venus-gps-and-arduino.html
Dr. Monk's DIY Electronics Blog, 2012.

4.2 Hardware Communication

In order to transmit messages to cell phones, the sensor must have a wireless communication module. Overall, Bluetooth is the best choice for the sensor to link with cell phones. Bluetooth is a wireless technology standard for transmitting data over a short distance. Bluetooth has two flavors of Bluetooth technology, Basic Rate/Enhanced Data Rate (BR/EDR) and Low Energy (LE). In the sensor, we will use Bluetooth LE to connect with a cell phone, and we will use a Bluetooth module to implement this function. Overall, we will use an Arduino to control all components (including Bluetooth module). Then we will program the Arduino, and the Arduino will control the Bluetooth module to communication with a cell phone.

Moreover, this project requires that different sensors can communicate with each other. There are some solutions. The first solution is using Bluetooth mesh. However, it has some disadvantages. The biggest disadvantage is that it is too new and it has very little references and materials. I think it is hard for us. The second solution is using ZigBee. This is a mature technology and it has vast materials that we can study. The last solution is using NRF24L01 module. This is a wireless communication chip. This module is also widely used and we can find materials about it easily.

After the sensor transmits data to a cell phone, this data also needs to upload to the server. This will use cellular mobile networks. Also, the server needs a port to receive data. I think we can use JSON to post data from the mobile phone application to the server. In the server, we can record all data from sensors and draw a vibration distribution map. This vibration location data can also be sent to the application, and alert riders about nearby road conditions.

[1]"How it works | Bluetooth Technology Website", Bluetooth.com, 2017. [Online]. Available: https://www.bluetooth.com/what-is-bluetooth-technology/how-it-works. [Accessed: 12- Oct- 2017].
[2] S. Mandal, S. K. Saw, S. Maji, V. Das, S. K. Ramakuri and S. Kumar, "Low cost arduino wifi bluetooth integrated path following robotic vehicle with wireless GUI remote control," 2016 International Conference on Information Communication and Embedded Systems (ICICES), Chennai, 2016, pp. 1-5.
[3] N. Pothirasan and M. P. Rajasekaran, "Automatic vehicle to vehicle communication and vehicle to infrastructure communication using NRF24L01 module," 2016 International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT), Kumaracoil, 2016, pp. 400-405.

4.3 Accelerometers

When we are riding a bike, it is very important to know the speed in real time. In some conditions, we might also need to know the acceleration. For example, in some downhill or ascent, it is hard to discriminate the condition when you are riding. If we got an instrumental which can show you the landscape, it is easy for us to determine slowing down or speed up. Accelerometers can be used to record these landscape conditions.

Reliability:

The exact accelerometer we are using are the SparkFun MMA8452Q. In order to ensure reliability, we need to make sure that the accelerometer can perform in ideal conditions. Basically, the core circuit is small enough to put into our protective packaging. It can experience interruptions if the component is not stable. We will need to make sure that it is fastened down and stationary in order to get accurate readings. There will also be other environmental conditions that we need to factor in.

To solve this, we plan to create a small—long box but that is shock-resistant and attach it to the bike frame. This way, we make it waterproofed and shock. It is also easy to repair. [1]

Collecting Information:

In some rugged road, we need to calculate the angle and the acceleration. It determines what speed is we needed, and show whether we should decelerated or accelerated. According to the introduction of this circuit, we need an external device (digital screen) to show this information. [2] Our accelerometer can toggle between g-ranges of +2/+4/+8. The lower the range, the more sensitive the components will be to movement.

Connection with Smart Devices:

Mostly, we need a terminal, such as SCM(Single Chip Microcomputer), which can input and output data with circuit, but it will cost more. However, to achieve this, the best way to is to design an application. [3] The problem is, we have not prepared for the application design yet.

Since we got the fund enough, we will consider solving this problem during the winter holiday, before we publish our progress officially.

[1] Ji, Cherry, Han, & Jordan. (2014). Electric bike sharing: Simulation of user demand and system availability. Journal of Cleaner Production, 85, 250-257.

[2] High-road, low road, and on the rough road: Adventure bike products: From lighting to seating to clothing--and everything in-between--aftermarket manufacturers are paying close attention to the booming ADVrider crowd with products for multiple motorcycle brands. (SALES). (2013). Dealer news, 49(5), 34-35.

[3] Sani, M. (2011). New software turns smart phones into bike computers. Bicycle Retailer and Industry News, 20(13), 12.

4.4 Global Positioning System (GPS)

Introduction:

With the advent of GPS technique measurements from is widely used in the measurement technology. Also, it becomes rather apparent that GPS plays a decisive role in rapid development of social because the GPS can guide correct route for people who use global position system, especially, recent advancements in the automobile industry have enabled “smart cars” to report road conditions from direct observations while driving by using GPS. These cars use a variety of sensors, most notably including accelerometers. Now, this project will build on that concept, but will instead focus on instrumenting a bicycle to report trail conditions. Therefore, GPS plays a critical role in reporting trail condition for a cyclist

Background:

The Global Positioning System (GPS), originally Navistar GPS, is a space-based radio navigation system owned by the United States government and operated by the United States Air Force. It is a global navigation satellite system that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. [1]

Design:

The system is based on real-time GPS data acquisition module getting the information of latitude and longitude [3]. Advantages of this system is mainly that through real-time GPS positioning, without human intervention, it can be accurate for automatic station in order to achieve energy and high reliability of the decadent. As shown in the figure 2, it is a flow diagram about GPS.

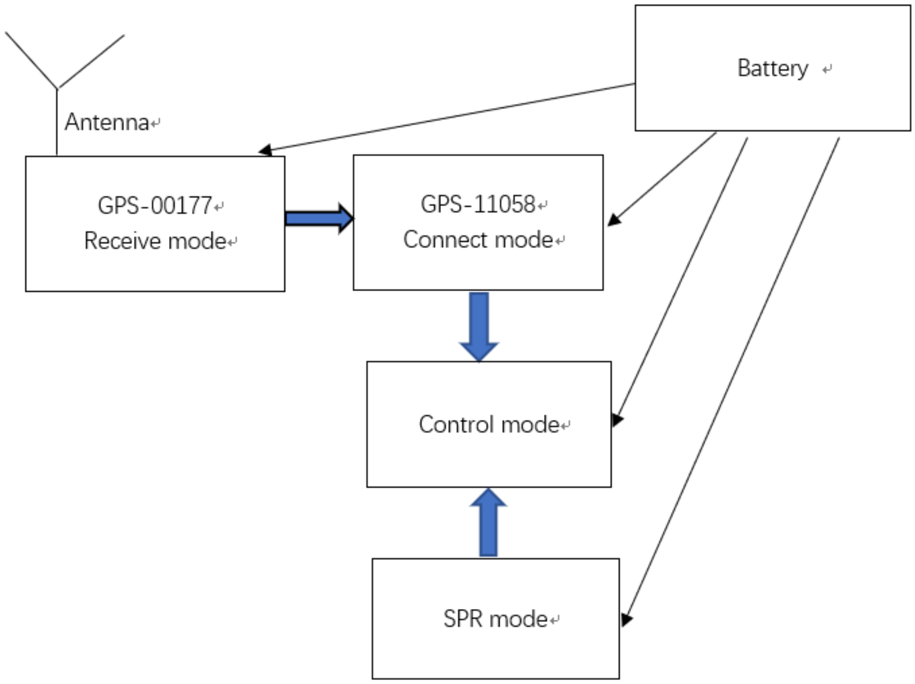

Figure 2: GPS function block diagram

Since the advent of GPS technique measurements from is widely used in the measurement technology, there was a major revolution. Compared with traditional methods, GPS control network, network scheme in both cloth or in the adjustment of the mathematical model of all have many differences [2]. Therefore, the study on how GPS principle and operating features of nets scheme formulated GPS about field observation and reducing the labor intensity, improve the quality and precision of observational results has crucial significance. This article mainly from GPS net zero classes designed, GPS nets kind of design, GPS nets of two types of design and GPS nets three design aspects, reference GPS control network should stick to four principles: the principle of giving priority to efficiency, high precision, reliability principle, the principle of the principle of funds, low GPS network optimization design discussion and research.

Nowadays, GPS is being applied almost everywhere, it is a very important factor in our lives. For example, Apple Watch is the most popular watch, it not only has GPS system, but also connect phone and transmit information to phone. Now, there are many products imitate this technology. Thus, our team believe that we can learn the GPS system from Apple watch. For instance, how to connect phone and transmit information to phone after the GPS-00177 get location.

[1] "GPS: Global Positioning System (or Navistar Global Positioning System)" Wide Area Augmentation System (WAAS) Performance Standard, Section B.3, Abbreviations and Acronyms.
[2] Winterberg, Friedwardt (1956). "*Relativistische Zeitdiiatation eines künstlichen Satelliten (Relativistic time dilation of an artificial satellite)*". Astronautica Acta II (in German) (25). Retrieved 19 October 2014.
[3] Howell, Elizabeth. "Navstar: GPS Satellite Network". SPACE.com. Retrieved February 14, 2013.

5.0 Requirements and Specifications

We have been given a list of parts that we have been provided by our sponsor. We will need to use all the components in *Figure 3* to develop our device. Most of the specs are based on these parts that we were given. Other components that are not listed include, at least two bicycles and a microcontroller used to communicate between software and hardware.

Line #	Qty	SKU	Product Name	UPC
1	4	DEV-13712	SparkFun OpenLog	845156006540
2	4	GPS-00177	Antenna GPS Embedded SMA	
3	4	GPS-11058	SparkFun Venus GPS with SMA Connector	845156003655
4	4	PRT-11366	Big Red Box - Enclosure	
5	4	PRT-11856	Lithium Ion Battery - 2200mAh 7.4v	
6	4	PRT-13777	SparkFun Battery Babysitter - LiPo Battery Manager Rechareable	845156007486
7	4	SEN-12756	SparkFun Triple Axis Accelerometer Breakout - MMA8452Q	845156006632
8	4	WRL-13764	Particle Photon (No Headers)	

Figure 3: Parts List from Sponsor

5.1 Mechanical

The mechanical characteristics of the project include the physical specifications of our final product. For example, size, weight, and packaging. Sometimes these are out of our control but other times they are very important for our client. Many of the parts that we will be using are provided by our client so in this case, size and weight are uncontrollable.

Requirements:

- Must be able to attach to a bicycle without obstructing the riding ability.
- The whole product must fit in the client's red box enclosure (74x158x90mm).

5.2 Electrical

Because there is a lot of software and hardware integration, electrical components are a big part of this project. These are characteristics that include power consumption, accuracy, and lifespan.

Requirements:

- The battery provided is rechargeable and should power the system for the length of a bike ride around campus (approximately 20-30 minutes).
- Everything needs to be powered by the 2200 mAh battery.

5.3 Environmental

These components are the type of conditions that the product will be able to operate at. When riding a bike, a rider and their bike will interact with many different environmental conditions such as water, dust, and vibration. To develop a system that is reliable we will need to factor in these conditions.

Requirements:

- The packaged part must be able to withstand vibrations and shocks from bumpy bike trail conditions.
- It will operate in normal working temperatures (0-60 C) and humidity conditions (<65%).
- The product's enclosure will be dust and moisture resistant.

5.4 Documentation

Documentation is a significant aspect of any project. These include, user guides, applicable code, and maintenance manuals. It is necessary in order to explain the team's findings to other people that are interested. Since this project will be continued and further developed after our year, our client will need all the work that complete.

Requirements:

- We need to document all of our work in an easy to understand format for our client and other technical readers who may want to expand on our development.

5.5 Software/GUI

As mentioned above, software-hardware integration is a big part of the instrumented bikes project. We will be using Arduino microcontroller and the free provided coding language for the Arduino.

Requirements:

- We need to document significant code used for the functionality of our product.
- Code should be commented so that steps are clearly defined and explained.

5.6 General

General requirements include things not mentioned in the first five categories. For example, timeline, client preferences, and vendor preferences.

Requirements:

- The project needs to be completed by May 2018.
- If class timeline allows it, initial product testing needs to start by the end of 2017.
- Communication should be working between multiple users.

6.0 Project Break Down

We break down the project into four subsystems, each of them have different solutions. These four subsystems include:

- GPS
- Accelerometer
- Battery (Power)
- Data Storage and Communication

We classify each level by identifying the function of this part. Also, we provide some possible solutions of the project by identifying these level-2 subsystems. We will also explain how each part fits into the overall solution.

6.1 Subsystems

Level.0 - Overview

This subsystem is based on data flow model.
In this data flow diagram, instruments get information from road condition, then output some warning signals to rider and store data to database.

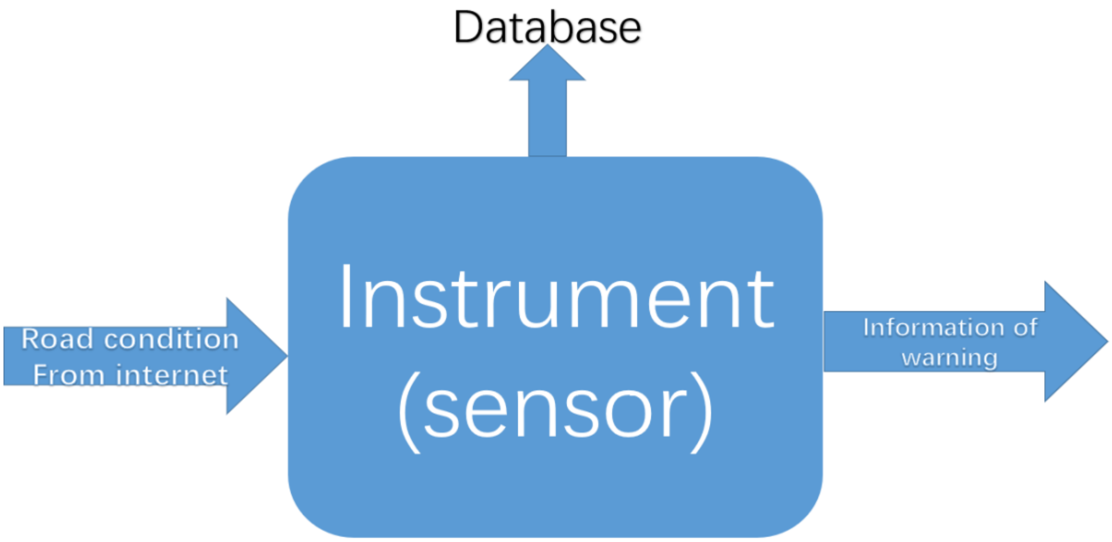

Figure 4: High-level component overview

6.2 Possible Solutions

Accelerometer Subsystems

1. Measures acceleration both horizontal axis and vertical axis.
2. Judging whether there are bumps or dips by collecting the acceleration of both horizontal axis and vertical axis.
3. Send data to communication system

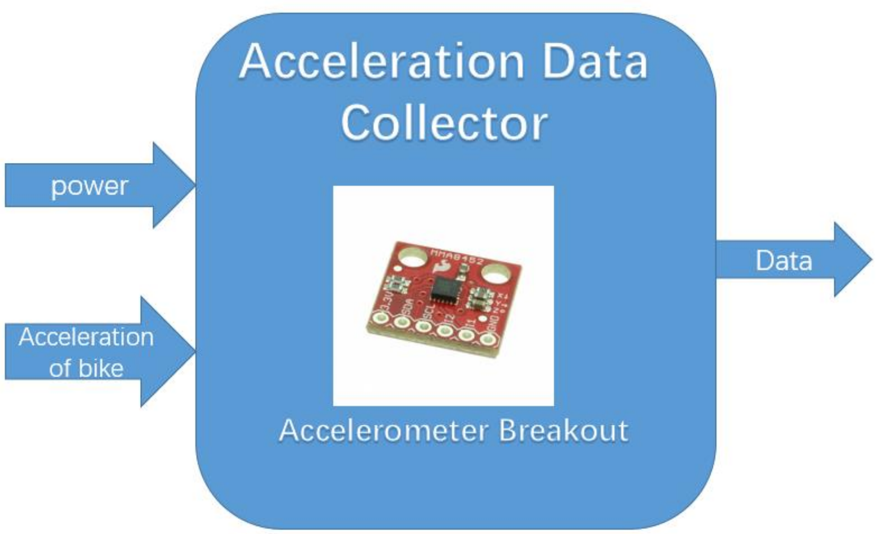

Figure 5: Accelerometer Function

GPS Subsystems

1. Provides geolocation and time information to a GPS receiver by using the longitude and latitude of the bike
2. Recording data when accelerometer judged a bump or dip
3. This will allow mapping accelerometer data to a point on the path
4. Send the location information to communication system

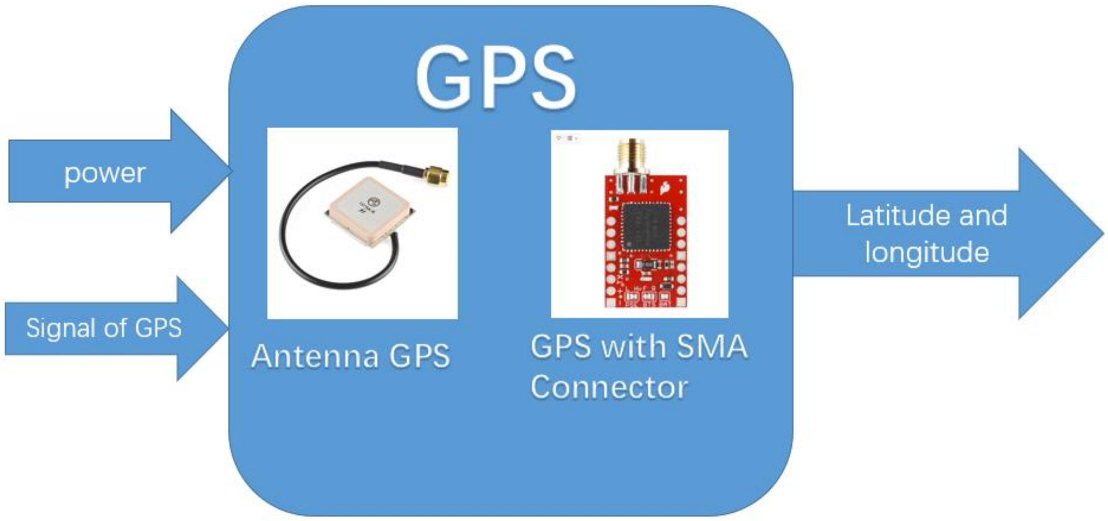

Figure 6: GPS Function

Battery Subsystems

1. Providing power to power electrical devices and sensor and mobility for our product
2. Maintain these devices and sensors with power for about 45 minutes at a time
3. Easily recharged

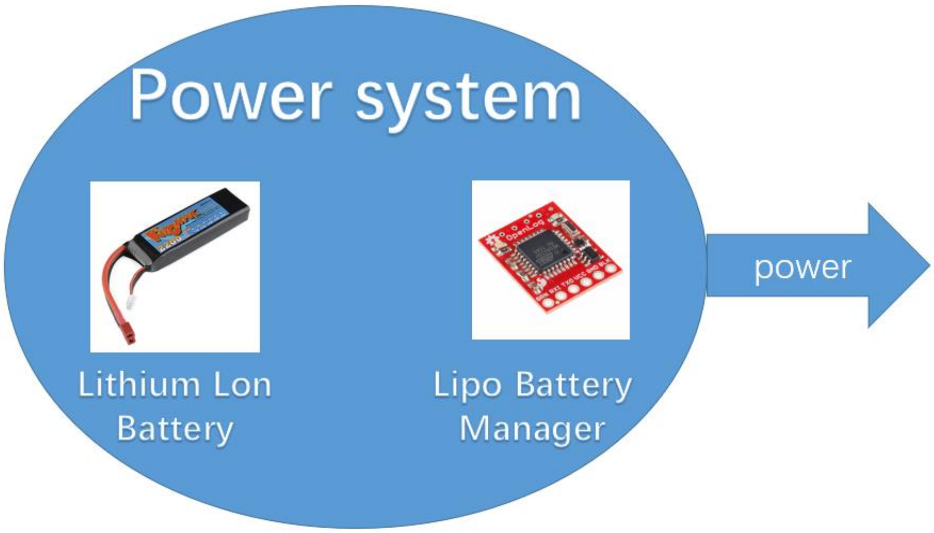

Figure 7: Power Supply Diagram

Communication & Data Subsystems

1. Use Open Log as local database
2. Photon can communicate with terminals
3. Photon send this information which is stored in Open Log

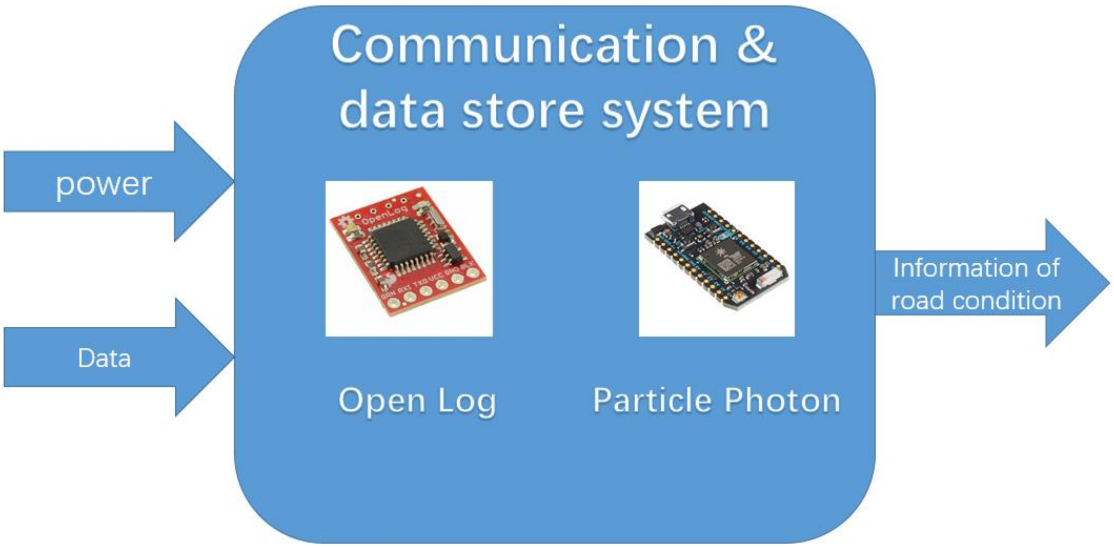

Figure 8: Data Storage and Communication

Level.1 – Detailed

In this level, we identify these subsections according to their function. Basically, this instrument includes accelerometer, GPS, Photon, and Open Log. Each of them have their own function and can work independent. So, we put them together to build a whole system and complete our product for our client. *Figure 10* below shows how we hope to connect all the subsystems of our project.

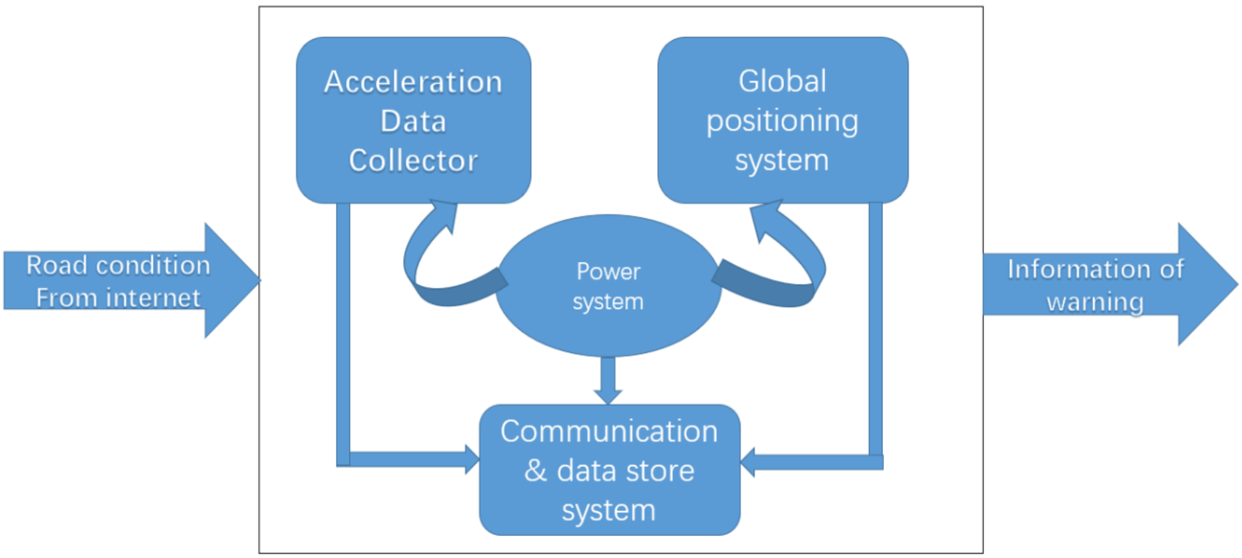

Figure 10: System Overview

Our project is a little different than most of the projects because we were given a parts list that the client wants us to use. We looked over the parts and the function of each one and we are confident that these parts will be sufficient. Because of this, we are doing the decision matrix a little different than deciding on actual component parts. In order to better plan how we will implement the subsystems and how much time and resources will used for each subsystem we are using a decision matrix shown in *Table 1*.

Table 1: Decision Matrix of Subsystems

Subsystem	Features	Time Required	Cost
Accelerometer	3	5	3
GPS	5	5	6
Communication	9	10	10
Power	3	3	3

By looking at the table above, we see that the hardest part for us in this project is the communication aspect. We feel pretty confident that we can show the accelerometer and GPS components working and connect it all to power. The Wi-Fi component will require the most time but we will work hard to make sure it works as expected.

7.0 Conclusion

In conclusion, this project is an addition to an ever-changing and advancing world.. First, our team defined the project that we were given. Next, we found some problems in current limitations, hardware communication, accelerometers, and GPS of the project. Then, we mention the requirements and specifications of these components about mechanical, electrical, environmental, and other important aspects. From this project, we are here to make the foundation for a society that has smarter and safer bicycles. We are excited to work on this project and develop a result that satisfies our customer. Our team will work hard to combine our expertise to create a working system. We will have a lot to learn but are committed to succeeding. Thank you for taking the time to review our status.