APPLICATION OF ACCELEOMETERS AND GPS CHIPS WITH ANDROID MOBILE APP IN ROAD CONDITION ASSESSMENT OF BIKE TRAILS

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Abstract

This research is mainly about the instrumented bike which uses lots of technologies such as *Geographic Information System* (GIS), *Global Positioning System*(GPS), mobile application development, data analysis and wireless network. The propose of this research is to detect the obstacles in the road, which will remind the bike drivers and the related departments. For passerby, the obstacles will endanger their safety, so the drivers may get hurt. For related departments, the research will help them to know where the obstacles are, then they can take a series of measures to fix these obstacles. Therefore, this research does not only ensure the bike drivers' safety but it also economizes the resources that government can use. In the research, our team adapts the data through GIS, GPS, and mobile app. For the adapted data, it will be proceeded data processing and analyzing. Some of the data could be defined on GIS, which ones are actual obstacles. The road testing was proceeding at Northern Arizona University. The test used one bike with a mobile phone (any Android phones) and the detected sensors to ride on a specific road which is across the entire school. During the driving, the app on the phone would work to adapt the data that contains latitude, longitude, the acceleration in the vertical direction and also the time. At the same time, it will appear a line chart to display the acceleration so that people can clearly to see the obstacles. If there is anyone using our app, they will receive the same data that will remind people to avoid the obstacles. Likewise, the data can be also updated to the related departments' systems that the maintain people can see the obstacles. Thus, they can decide to repair which one first.

Introduction

The research is related to the bike lanes. That means the main work is to detect the bike lanes to ensure that the bike drivers will not get hurt. The obstacles which have encountered so far are mainly bumps. Therefore, finding bumps is the most important thing for the research. When someone rides the bikes on the road, the device that are the phone and computer will be received thousands of data. Thus, there is lots of data to analyze. First, there will be some data showing that are the bumps. Second, the collected data will be displayed on the map. Third, the final data will be uploaded on the website for the users to use. However, this is a huge work for the first-time people to finish because the workers need to do much riding work on the road to find the bumps. It will spend a lot of time and energy, but it is just for the first time. Once, the first time the bumps have been all detected. The future work is to determine whether the bumps are fixed or not, but it does not represent there is no work needing to detect the bumps in the future. When the road is finished and to use, it will have a life just like human. For now, maybe just this place have bumps, however, in the next days, it will appear more bumps on other places. Thus, regular checks are needed to determine if there are new bumps appears. The appropriate time for checking is once a year. The related departments could use our research to determine the bumps on the vehicles' road, not just the bike lanes. In daily life, when people are driving if drivers don't pay attention, they may hang up the chassis because of the bumps. People could avoid this situation via using the research. The bumps can be seen on the mobile phones. Before people are riding across the bumps, they could know there is a bump that needs to be slow. This paper will introduce what kind of way and how we achieve what we did to realize the function that is about checking road and reminding people. The content will include the components, the prototype, the software, and the Android studio.

Overview of road condition assessment

Using the technologies that the paper mentioned is not the first one. Before this paper born, Kongyang Chen and Guang Tan have already used GPS to find the bikes which do not be used, so people can find the idle bikes on the phones so that they could ride the bikes [1]. This research used the same technology to define the bumps instead of bikes. To determine the bumps on the map may be a litter easier than the bikes. Bikes can be dropped anywhere but the bumps will always be there. For the data acquisition, Eric Dennis's team had proceeded that used the cars to detect the road condition [2]. This is a similar approach to detect the roads. This research absorbs some ideas from Eric's research. The most important point is using the geographic system to monitor the roads. Under Roberto Montanari's research, his team studied an assistant system that can help riders in many ways. The navigator system and speed alert system are helpful [3]. When bike riders encounter bumps, there will be a reminder to alert people, or when one rider finds a bump, the other riders will receive the bump message. Besides, now that in this research people should use map a lot, so the navigator system can be connected more or less. Stephen Smaldone contribute a model, the cyber-physical bike. It can help avoid the collision between bikes [4]. This will give more details about how to refine this research's reminder.

HARDWARE SYSTEM

For this part will mainly talk about the hardware system of the project, which is the basics of the whole function design. Once the hardware system is finished, other components can be combined together. For example, GPS can collect latitude and longitude, the accelerometer can detect the accelerations in the X, Y, and Z direction. Openlog is able to store all of the data and is readable on the computer.

Work Flow

For hardware, the first practice is Particle Photon with the example of Led to make sure it functions well. It is the most important step because the Particle Photon serves as a microcontroller in the project. Once the GPS and accelerometer were tested perfectly, the data could be shown in Figure 5. The picture shows the correct location information with Date and UTC time which is collected by GPS, and the data format is set as shown which used signs '|' and '=' to represent the intensity of value collected by the accelerometer (Figure 6.). Once the hardware system is done, the next step is the mobile app development and wireless transmission between the Photon and the mobile app using TCP/IP protocol.

Components Introduction

The first important component is GPS (Gowoops GPS Module U-blox NEO-6M with TTL Ceramic Passive Antenna), which compatible with 3.3V / 5V level, and various parameters can be set via the serial port, convenient for connection to a variety of microprocessor systems. The second pivotal component is the accelerometer (Spark Fun Triple Axis Accelerometer – MMA8452Q). SO, two accelerometers in one set of the system in order to collect accurate data, one place on the front of a bike, another place on the back. The last component for hardware system is Openlog (Spark Fun Openlog), it is an open source data logger that works over a simple serial connection and supports microSD cards up to 64GB, also can store or "log" huge amounts of serial data and act as a black box of sorts to store all the serial data that other components generate.

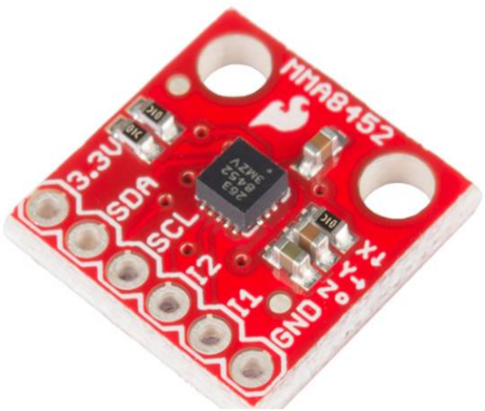

Figure 1. Accelerometer

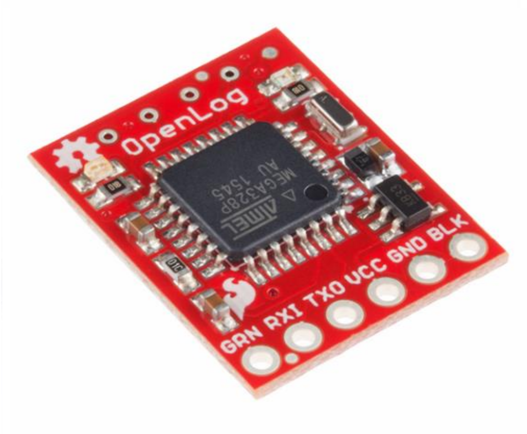

Figure 2. Openlog

Components Functions

Firstly, the basic function of GPS is collect the correct location information, longitude, and latitude. the purpose of using GPS is that once the system detects a bump or hole on the road, it can record the location of these bumps and alert neighboring biker through the Android platform based mobile app. In fact, GPS can also record the data and UTC time, but it is unnecessary for us to use it. The accelerometer that used is triple axis accelerometer which means it has three directional values (x, y, and z), but what mainly use to do data analysis is the direction of z because the z value will get an obvious vibration when bikes go through a bump. So, all the bumps can be distinguished easily only if compare these vibration data with those data that when bikes in normal roads. The last part of the hardware system design is the Openlog, the major function is store data and gets prepared for the data processing later.

In a word, the function of GPS is to get the location information and indicate where these bumps are, the function of the accelerometer is defining the bump by watching the vibration of the z value, and the Openlog is mainly in charge of data storage.

Hardware Connection

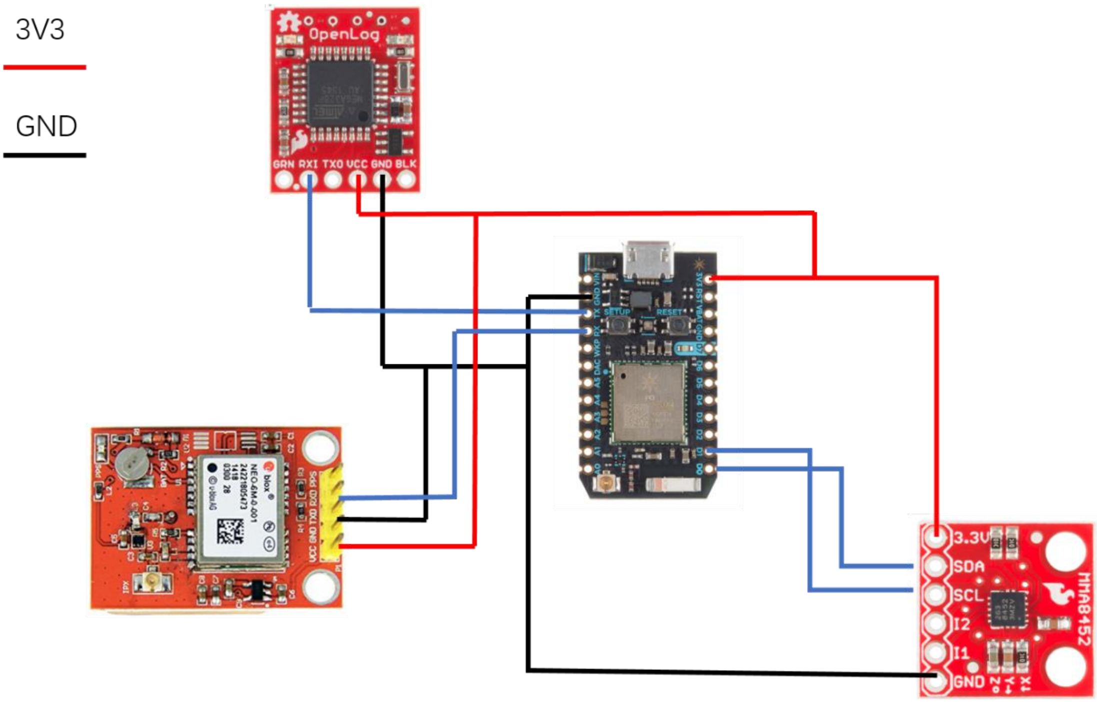

Figure 4. Hardware Connection

As for the hard connection, the pins defined as following:

Photon		Acc	Photon		GPS	Photon		Openlog
GND	→	GND	GND	→	GND	GND	→	GND
3V3	→	3V3	3V3	→	3V3	3V3	→	3V3
D0	→	SDA	Rx	→	Tx	Tx	→	Rx
D1	→	SCL						

Accordingly, the system shown in Figure 4 is placed into a box and install this set of a system on the back of a bike. Besides, another box with a single accelerometer is placed on the front of the bike with a platform in order to improve the accuracy of the data because two sets of data from two accelerometers can be compared and provide the proof to distinguish whether it is a bump or not. And the installation is demonstrated below.

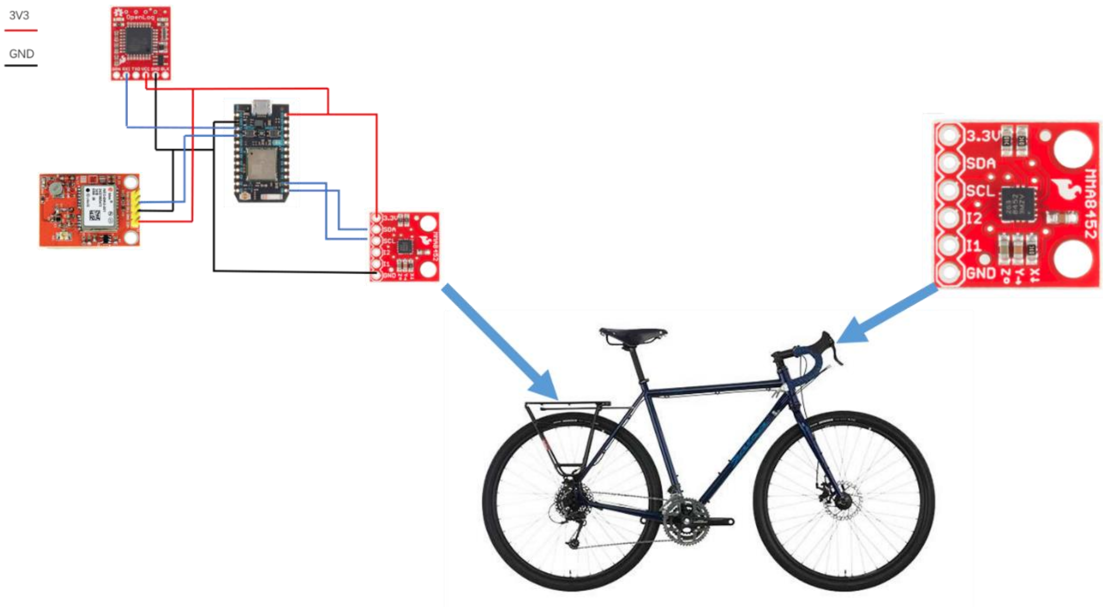

Figure 5. Hardware Installation

Wireless Transmission

As we know, the wireless communication is one of the most popular and convenient methods to transmit data. Hence one of the major functions of the mobile app it to achieve that phones can receive data from Particle Photon using TCP/IP protocol. Fortunately, the Photon provide the method which can make the Photon works as 'client' and phones can work as 'server' only need the correct IP address and port number of the phone while transmission, of course, phone have to open 'hotspot' to make sure Photon can connect with Photon physically. Besides, the result is shown below after the data format has been adjusted.

192.168.43.199 - PuTTY

```
Date: 180118
Latitude: 3510.5198
North/SouthIndicator: N
Longitude: 11139.4567
East/WestIndicator: W
X:                     |                     (-0.08 g)
Y:                     |=                    (0.03 g)
Z:                     |==========           (0.99 g)

UTC Time: 032237.617
Date: 180118
Latitude: 3510.5198
North/SouthIndicator: N
Longitude: 11139.4567
East/WestIndicator: W
X:                     |                     (-0.08 g)
Y:                     |=                    (0.03 g)
Z:                     |==========           (0.98 g)

UTC Time: 032238.617
Date: 180118
Latitude: 3510.5198
North/SouthIndicator: N
Longitude: 11139.4567
East/WestIndicator: W
X:                     |                     (-0.07 g)
Y:                     |=                    (0.03 g)
Z:                     |==========           (0.98 g)
```

Figure 6. The result of transmission

Data processing

Data processing is the process of extracting valuable information from massive raw data, that is, data is transformed into information. In this experiment, the raw data is what the accelerometer detect at a certain point with the longitude and latitude. The propose of this experiment is that finding some parts of road which can be regarded as bumps and holes and providing these information for the driver and government maintenance office. The most direct way for people to distinguish the points needed to be repaired is to show the exact location on the Google map. Also, it is what data processing do.

• Accelerometer)1

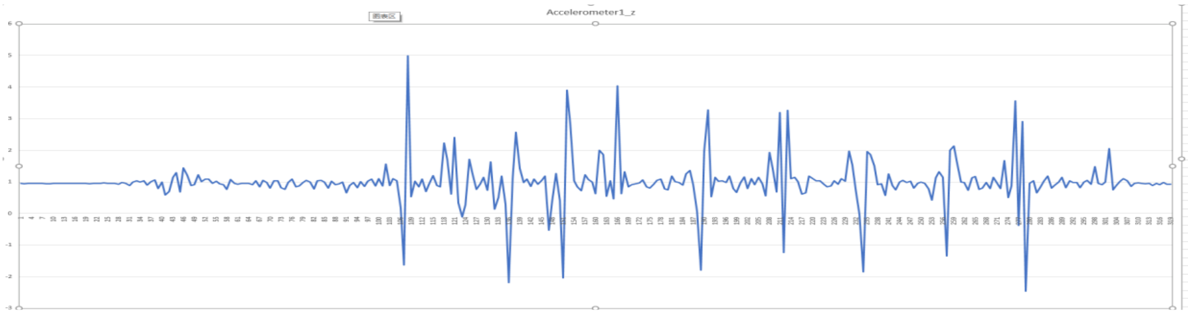

Figure 1 ten pipes test

When choosing a method to process these data, there are some factors and problems needed to be considered. In Figure 1, it is easy to find which point is higher and lower than a certain threshold to be set up. However, when a bike goes through a hole or hump, it will go up and go down or go down first and go up. Therefore, that simply taking all points reaching a certain threshold as holes or bumps will make the result of calculations double or triple. Another problem is that it is hard to determine a threshold before several times of experiment. After the data was calibrated during the interpretation of data, a predetermined scale can be found and used in our data processing. The traditional methods such as Fast Fourier Transformation and Moving Average, although popular methods used in many fields, are not for this situation. For example, FFT is a kind of algorithm that can sample points and transform them from time domain to frequency domain. However, the problem is that it is hard to make one-to-one match between the original data and processed data. Therefore, combining some different methods and creating a new method is the best option.

This new method is that dividing line chart into so many pieces with same range called windows. During biking and data collecting, the bike was going at the rate of 15 miles an hour. And our frequency of collecting data is 20Hz. Therefore, the windows range is set up 10 times in Figure 2. Also, in every window, if there exist a maximum value minus minimum is larger than 2.5g, there must be a point that should be considered as a hole or bump. After making sure there exists a pavement problem during this range, it is critical to find the exact point in this window. For example, in Figure 2, after calculation only point A and C can be taken as a hole or bump, because the range from minimum to maximum is larger than 2.5g in one window. The lowest co-ordinate in window A is (107, -1.62) and the highest one is (109,5.00). Therefore, the exact location should equal to (107+109)/2 = 108.This is how this method identify pavement problem locations. There must be a consistent one-to-one match between every point on x-axis and latitude and longitude for a location. Finally, the points that fit into our standard will be showed on mobile application.

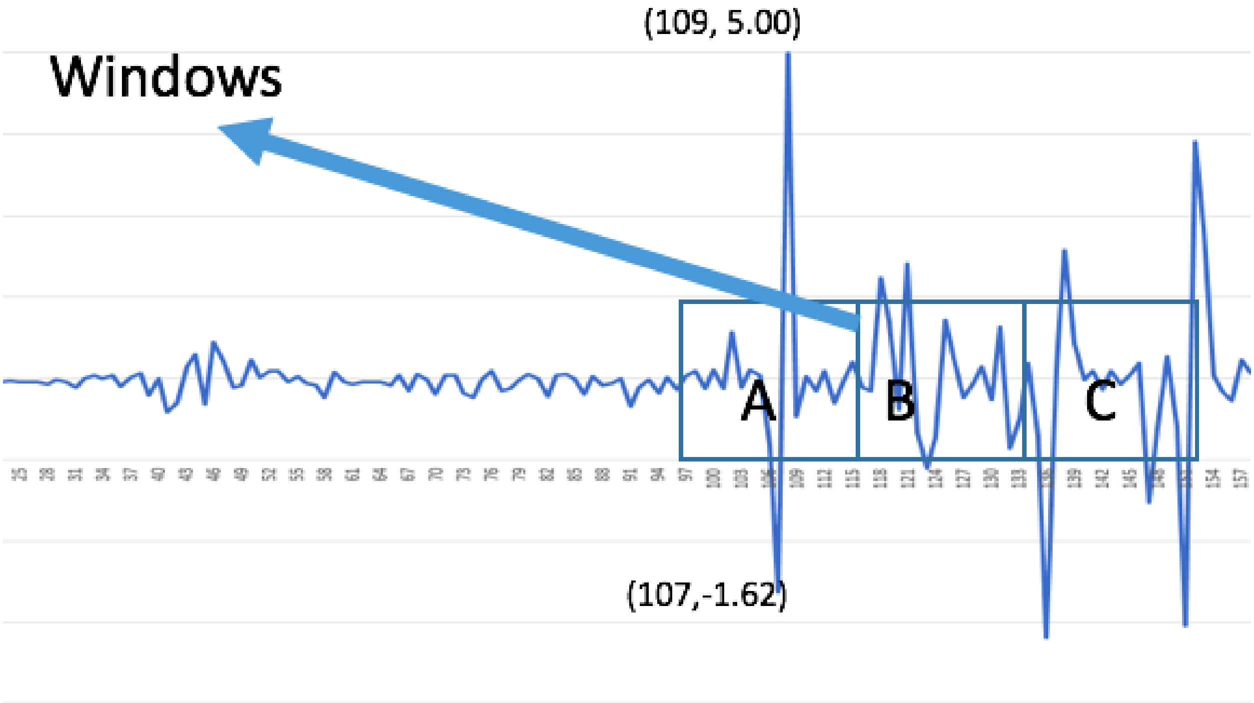

Figure 2 ten pipes test with windows capture

GIS

Geographic information system(GIS) is a system used for analyzing and managing data. It has high performance in visualizations based on maps and 3D graphs. In the case of excessive data filtration and analysis, GIS can reach the deep logic behind the massive database to analysis patterns, relations reflected by these data. GIS is widely used in mapping, urban planning, accident analysis and hot spots analysis. In this project, we mainly use GIS as mapping and bumps analysis.

Since the goal of this project is filtering barriers on roads and detecting bumpy pavements, we need to analysis and choose points that may form obstacles for bikes on maps. Smooth roads would not be shown on the detecting results. Some sections of roads are not smooth or have obstacles on roads. Hollows and bulges on these sections will cause unstable bumps of bikes, these points needed to be detected and shown on result maps. Data is collected first, then GIS can provide powerful functions on points choose and visualizations. To collect data, three paths in Northern Arizona University are chosen as experimental paths as shown in Figure 1. These three paths cross the north and the south of campus, they are long enough to include all kinds of pavements. The points causing bikes' bumps are called "Bump points". In this project, "Bump points" will be detected and shown on maps.

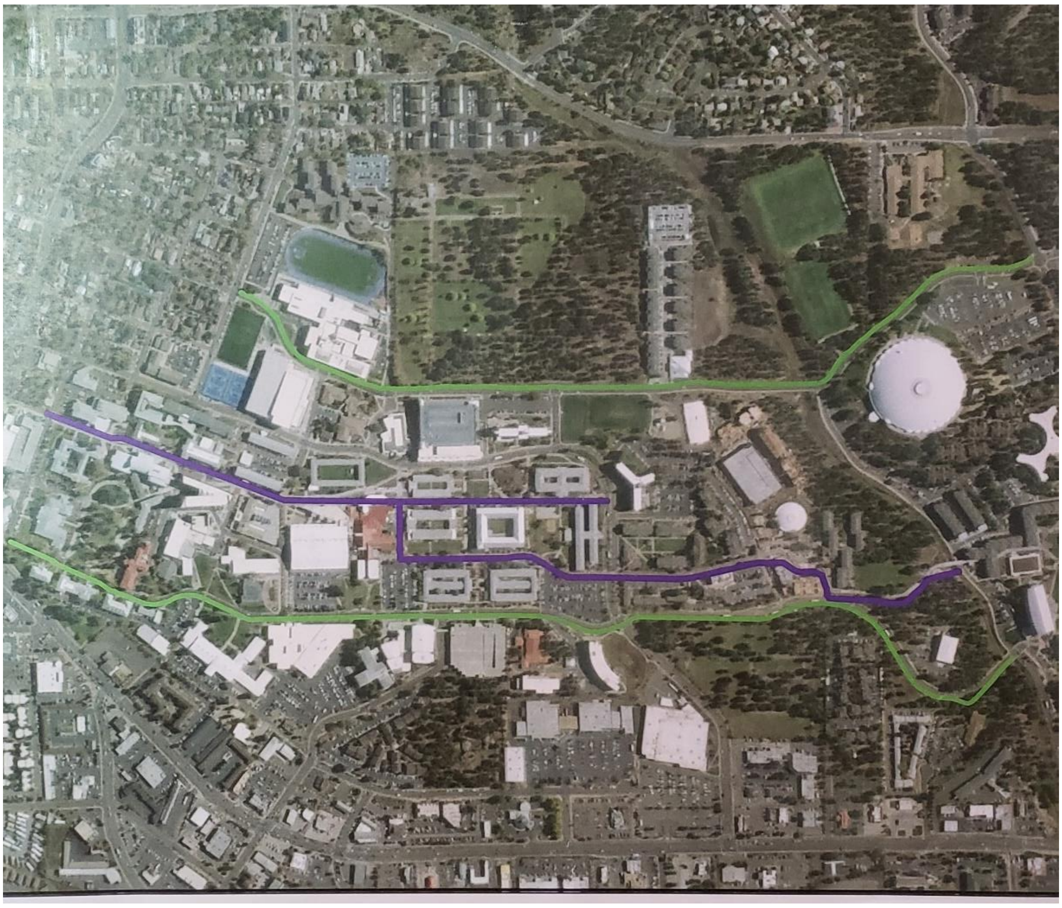

Figure.1 Preliminary test on the three paths

Gather and select data

In the project, there are two components are used to gather the data are respectively GPS and accelerometer. At first, collecting data from all the points on the road is the preliminary task. About the GPS, we use the to get the latitude and longitude based on programming of the microcontroller particle photon. These data would be exported to .txt or .excel file format in Figure 2(a). Once all the coordinate data be collected, they could be processed to the specific .csv file format of the ArcGIS shown in Figure 2(b), the first column is the number of the data, the second and third columns are respectively latitudes and longitudes.

	A	B	C	D	E
1	1730543	-111.656	35.17861	0.94	0.96
2	1730611	-111.656	35.17861	0.94	0.96
3	1730678	-111.656	35.17861	0.93	0.95
4	1730746	-111.656	35.17861	0.93	0.98
5	1730815	-111.656	35.17861	0.93	0.97
6	1730881	-111.656	35.17861	0.93	0.96
7	1730949	-111.656	35.17861	0.93	0.96
8	1731084	-111.656	35.17861	0.93	0.97
9	1731152	-111.656	35.17861	0.93	0.96
10	1731220	-111.656	35.17861	0.94	0.96
11	1731291	-111.656	35.1786	0.94	0.97
12	1731356	-111.656	35.1786	0.93	0.98
13	1731435	-111.656	35.1786	0.93	0.98
14	1731491	-111.656	35.1786	0.93	0.96
15	1731558	-111.656	35.1786	0.94	0.96
16	1731629	-111.656	35.1786	0.93	0.96
17	1731694	-111.656	35.1786	0.93	0.99
18	1731766	-111.656	35.1786	0.93	0.98
19	1731830	-111.656	35.1786	0.94	0.97
20	1731908	-111.656	35.1786	0.93	0.98
21	1731965	-111.656	35.1786	0.94	0.96
22	1732033	-111.656	35.1786	0.94	0.99
23	1732099	-111.656	35.1786	0.93	0.96
24	1732171	-111.656	35.1786	0.94	0.96
25	1732246	-111.656	35.1786	0.94	0.97
26	1732303	-111.656	35.1786	0.94	0.97
27	1732384	-111.656	35.1786	0.93	0.97
28	1732442	-111.656	35.1786	0.94	0.96
29	1732508	-111.656	35.1786	0.93	0.97
30	1732580	-111.656	35.1786	0.94	0.97
31	1732650	-111.656	35.1786	0.94	0.97

Figure 2(a) Gather Data

	A	B	C	D
1	OBJECTID	Latitude WGS84	Longitude WGS84	
2	1	35.178612	-111.655937	
3	2	35.178612	-111.655937	
4	3	35.178612	-111.655937	
5	4	35.178612	-111.655937	
6	5	35.178612	-111.655937	
7	6	35.178612	-111.655937	
8	7	35.178612	-111.655937	
9	8	35.178612	-111.655937	
10	9	35.178612	-111.655937	
11	10	35.178612	-111.655937	
12	11	35.178596	-111.655952	
13	12	35.178596	-111.655952	
14	13	35.178596	-111.655952	
15	14	35.178596	-111.655952	
16	15	35.178596	-111.655952	
17	16	35.178596	-111.655952	
18	17	35.178596	-111.655952	
19	18	35.178596	-111.655952	
20	19	35.178596	-111.655952	
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22	21	35.178596	-111.655952	
23	22	35.178596	-111.655952	
24	23	35.178596	-111.655952	
25	24	35.178596	-111.655952	
26	25	35.178596	-111.655952	
27	26	35.178596	-111.65596	
28	27	35.178596	-111.65596	
29	28	35.178596	-111.65596	
30	29	35.178596	-111.65596	
31	30	35.178596	-111.65596	

Figure 2(b) Formated Data

ArcGIS Pro is a powerful tool which can manage data, make maps and visualize analysis. Many data formats could be imported and exported in this software. It can also visualize the chosen points on the map clearly. ArcGIS pro can reach all the requirements of this project. In this software, the data could be imported to the map by creating a new XY Event Layer, and it has three main parameters are respectively Table, in-x-field, and in-y-field. Table means the table containing the x- and y- coordinates that define the locations of the point features to create, X Field and Y Field mean the field in the input table that contains the x-coordinates and y-coordinates. Then all the point will be shown on the map by the geoprocessing, and it could display the significant information including match-address, x and y coordinates.

About the accelerometer, based on different damping systems, we use the high-performance shock-absorbing bicycle. Accelerometers are used to determine x, y, and z axis acceleration. The z axis acceleration is the most important since this value will determine the filtered points. One threshold value is needed here to determine “Bump points”. The maximum value of z acceleration force minutes the minimum value of z value is compared to threshold. Once the value accelerates the threshold, the point will be classified to "Bump points". The threshold is taken as 2.9 to 3.1 because this value can accurately reflect the hollows and bulges on road. In figure 2(c), it shows the mapping of result in the ArcGIS pro. First step is importing all data to get the path which the rider goes through, and it would be displayed by the green points. Second, after the data be formatted, it would be compared to the threshold and be filtered. Then the filtered data will be imported into the ArcGIS again and shown as the red points.

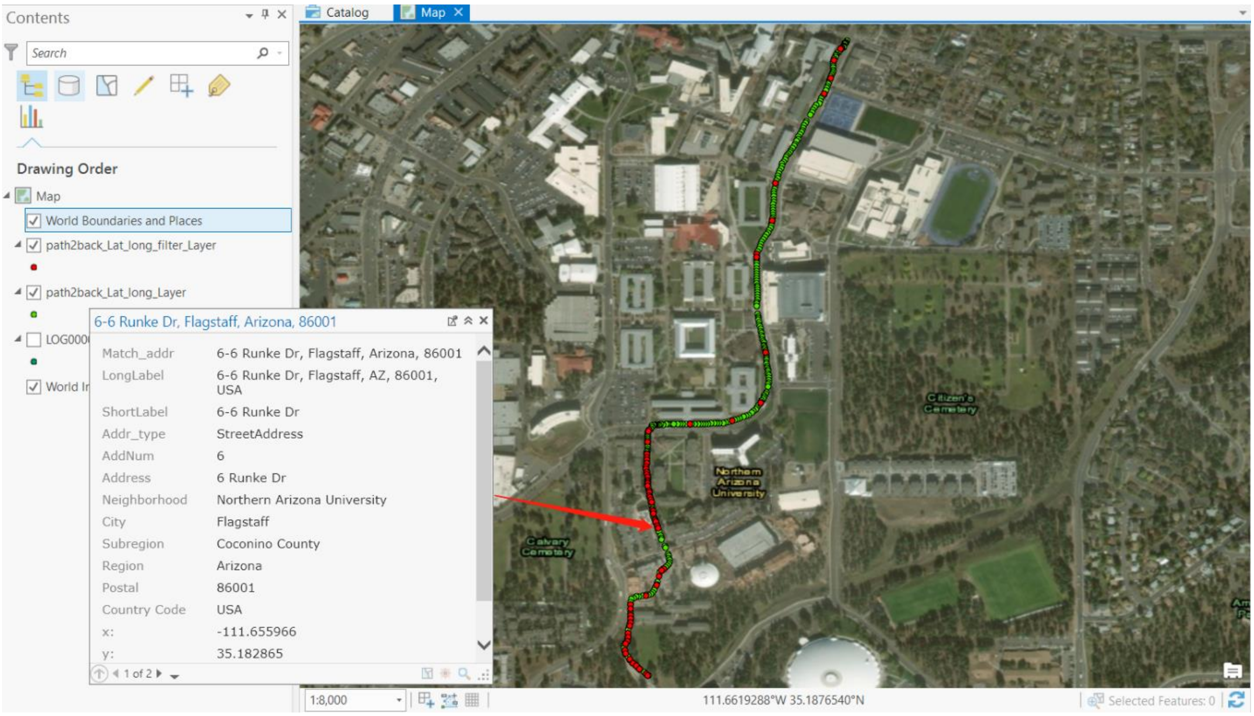


Figure 2(c) Display the data of the path and the bumps

Application

The GIS results can show clearly the road conditions detected by Instrumented bikes. Accompanied by the exponentially increasing number of bike users, the road detection is essential to learn about the condition of the road, especially those roads that vehicles are not able to arrive. One important application is providing information on bumpy road to infrastructure maintainers. These results help to provide recommendations to decision makers for improving the efficiency and ubiquitous use of bike mobility. It will also help those who ride bicycles at night avoid traffic accidents. The users can learn about the real-time information of the road through apps on the phones to avoid the traffic accidents.

Mobile application

Firstly, according to the request, one of the purposes of this project is to notify other bikers of locations of bumps. Smart phone is a feasible way for users to communicate with each other and get the visualization of bumps. Thus, in order to better realize the communication between bikes and make the visualization of bumps, a mobile app (Bike) is developed based on android. The fundamental functions of this app include data collection and restoration from accelerometers and the GPS chip (Figure 2), data visualization of the value of accelerometers in real time (Figure 3), data analyzing of accelerometers, bumps visualization using google maps API (Figure 4), data sharing based on Firebase (Google Cloud), and finally user interfaces (Figure 1). This app is different from the vibration monitoring mobile apps in Google Play (Android system) or Apple Store (iOS system) which use the accelerometer sensors inside of the phone to record the vibration intensities. Instead, in this self-developed Android application, the value of accelerations and location coordinates are transmitted from the hardware system (Figure 5) on the bike. This method is more accurate than the traditional method since the accelerometers and GPS chip both have high sampling range and frequency (accelerometer is up to 800Hz, GPS chip is up to 10Hz).

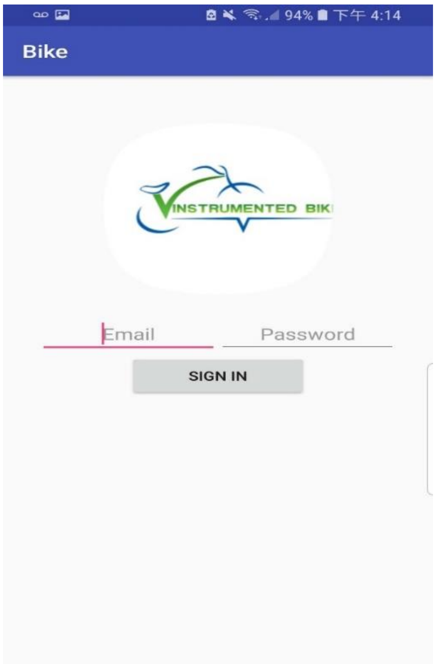
The whole application works as following steps:

1. Sign in the application with given user name and password (user name and password should be given in the firebase dashboard).

2. After sign in successfully, the page jumps to app dashboard. In this page, users can start/stop data collection, which is based on TCP/IP protocol using hotspot, with their own file name.

3. After successfully start the activity users could receive the data (vibration in X, Y and Z coordinates (g), latitude (degrees), longitude (degrees)) from hardware system, simultaneously, these received data is stored in the phone and transmitted to the cloud (Firebase). All the data can be stored in Firebase real-time database (Figure 6), and vibration intensities are still able to be manifested by the line chart inserted in this app. Additionally, this line chart is also in real time which means once the new data is received, the line chart would automatically refresh.

4. Moreover, users can also choose to open to the google map to see the location of bump. The google map activity will automatically synchronize with Firebase to withdraw the data. According to the fact that Firebase real-time database is a cloud database, all the users are able to synchronize data simultaneously. Then after filtering the data, the bumps will be manifested in the form of red markers in the google map. Once the bump is added, the app will calculate the distance between all bumps and user's current locations. If the distance is less than 100 meters, the notification would be appeared in the form of sound and text on the screen. Still, the google map activity is in real time, which means that users can press the start button on the dashboard page and then jump to map page, once the new bump detected, users can also see it on the google map.



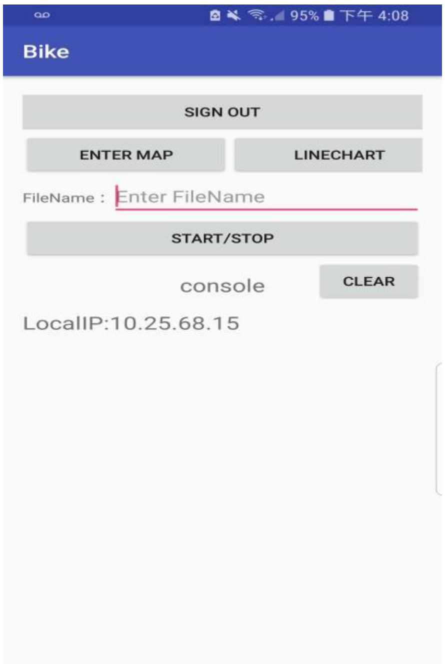
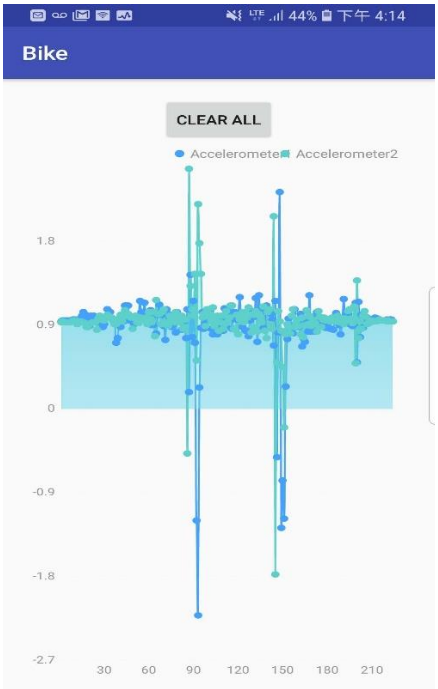


Figure.1 User Login.

Figure.2 Data Collection and Dashboard.



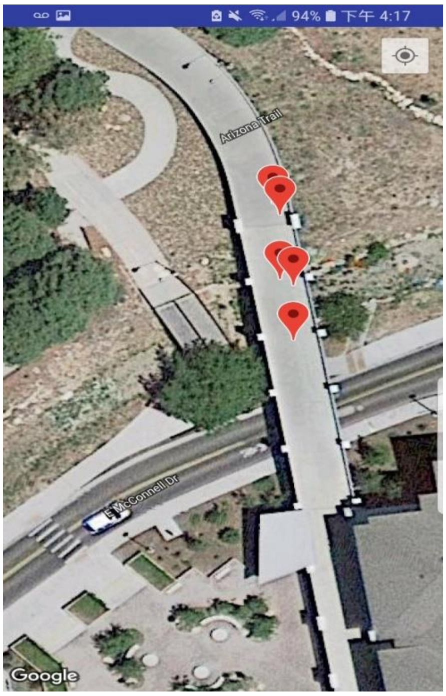


Figure.3 Line Chart of Accelerometer.

Figure.4 Google Map with bumps.

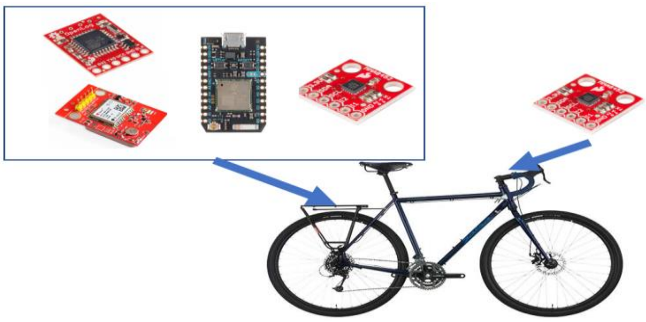


Figure.5 Hardware on bike.

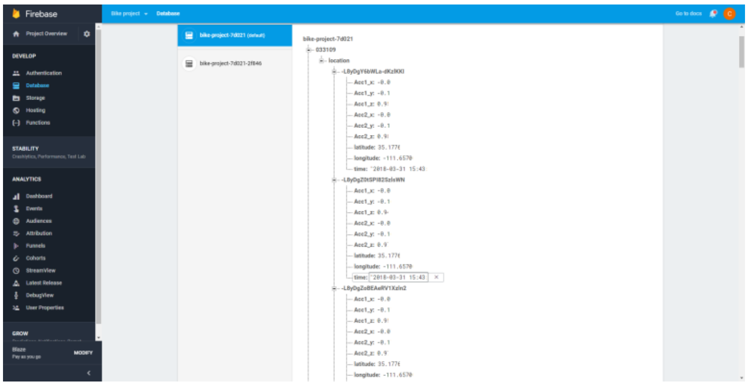


Figure.6 Data in Firebase real-time database

Test Result:

In this test, ten artificial bumps (pipes Figure 7) are used to test accuracy of this application.

The distance between first five bumps is almost 1meter, while distance between the last five bumps is 3 meters. The mapping appeared on the google map matches the number of bumps, locations of bumps, as well as the distance between bumps. Thus, this application is accurate to detect the bumps. Additionally, the data from Firebase real-time database is able to be synchronized by all users, which means all users could see the same result on the google maps.

Figure.7 Mapping to artificial bumps (on the right side)

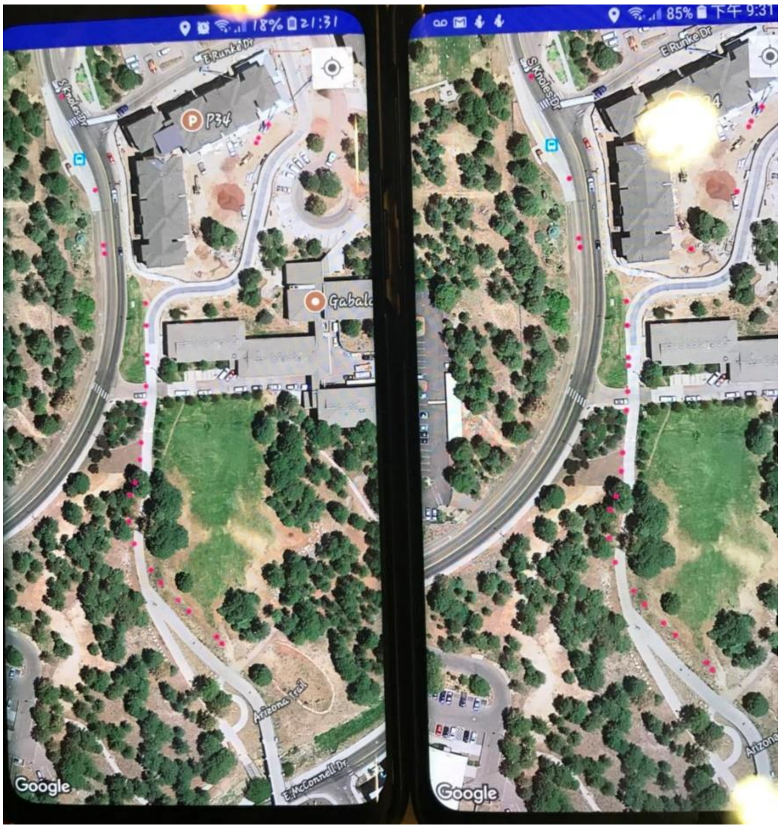


Figure.8 Test result of campus biking road on two phones