ECE1778 HowBumpy Project Final Report

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Word Count: 1688

1 Introduction

Speed bumps are devices that use vertical deflection to force a vehicle driver to slow down. For some types of speed bump, the ones on King's College Circle[1] to be specific, are not serving their purpose. It feels really bumpy when you normally drive over it but it seems you can barely feel its presence when you drive over it above certain speed. So, is there any correlation between the speed you drive over the speed bump and the bumpiness you feel? A mobile application called HowBumpy is designed and build to specifically answer this question. By utilizing the accelerometer and GPS inside a smart phone, the App can measure the bumpiness and the speed of a car. By driving over the target speed bumps at different speed, it should be able to obtain enough data to plot the chart of bumpiness vs. speed.

2 Overall Design

Figure 1 shows the block diagram for the top-level application design.

The Data Process block gathers data from the sensors and perform operations like filtering, smoothing and averaging. Then the processed and meaningful data (speed, bumpiness, location) are send to the Data Storage block and stored in a database. The user can configure some of the parameters in the Data Process block such as the threshold values for auto detection. User also have direct access to the processed data such as the the list of bumpiness/speed data in the database.

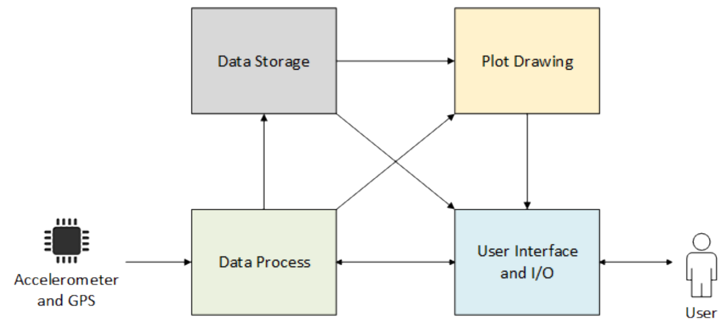

Figure 1: Block Diagram for the Overall Design

The Plot Drawing block visualizes both the raw sensor data and processed data to the user, so that the user can see either the real time accelerometer data through a chart or the speed vs. bumpiness plot.

3 Statement of Functionality

3.1 Database Management

Since difference car has difference suspension system, wheel size, tire type and many other variables that will affect measurement result, it is necessary to have different profile for different cars, which is exactly what you can do with this application. As shown in Figure 2, you can create a profile by clicking the NEW PROFILE button, enter a profile name and click CREATE. In Figure 3, you can see a list of measurement data clicking the name of specific profile. A plot that visualizes all the measurement data will show up if you click the SHOW PLOT button. Deletion of the profile or the data is also very simple, just swipe the element you want to delete and confirm the deletion

[1] A circular road within University of Toronto

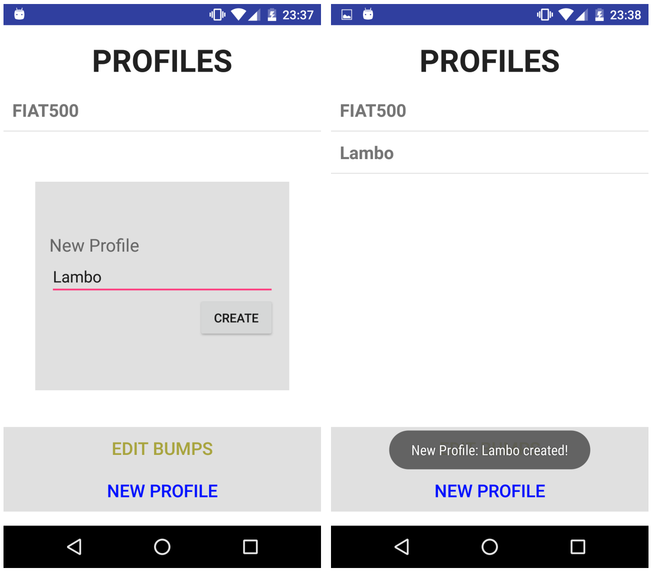

Figure 2: Create a Profile

by clicking YES, DELETE as shown in Figure 4. Finally, click the NEW MEASUREMENT button will bring you to the measurement panel.

3.2 Measurement

This section shows how the application quantify bumpiness and the two modes for measurement: manual mode and auto mode.

3.2.1 Quantify Bumpiness

The normal accelerometer does not exclude the gravity of earth, so the 9.8 m/s^2 is always showing on the acceleration readings even the phone is stationary on the table. This application uses "linear accelerometer" which automatically removes the gravity.

Bumpiness essentially is the sudden change of vertical acceleration, so the difference of previous and current acceleration are used to quantify bumpiness. For each acceleration reading, it is compared with the value from previous time step, and their difference is calculated. To smooth the data, the average of 19 previous and 1 current acceleration difference values is calculated. This average value is counted as the quantified bumpiness value for current time. And finally the bumpi-

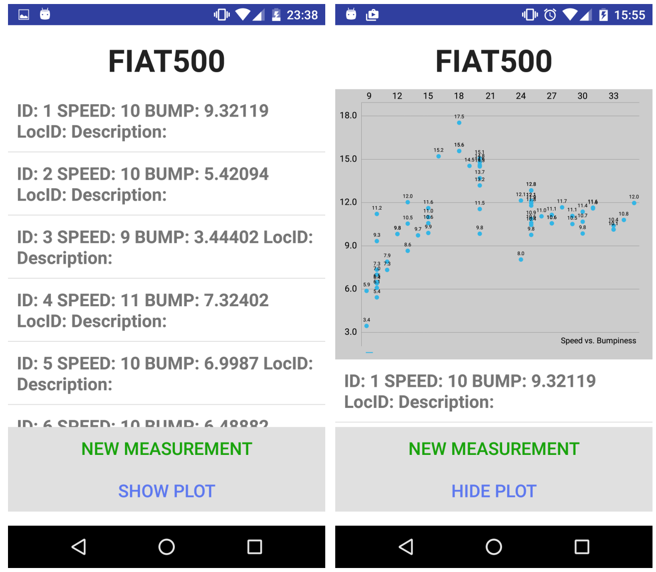

Figure 3: Data of a Profile

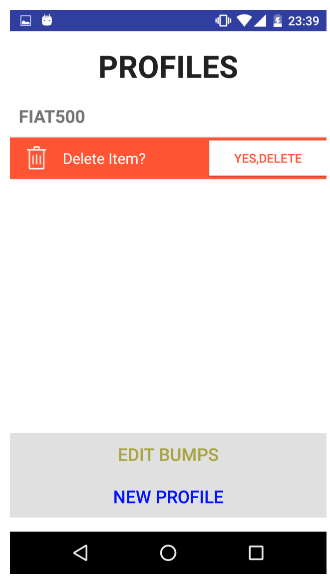

Figure 4: Deletion

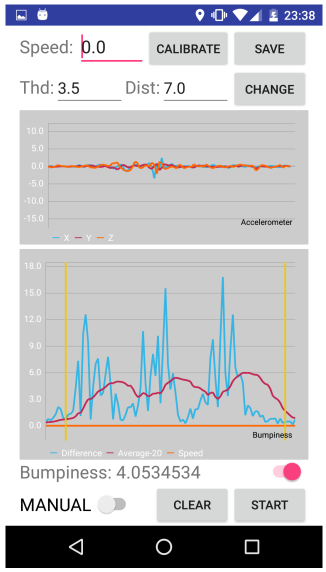

Figure 5: Manual Mode

ness value over a period of time is the average bumpiness value for that period. Please noted that the acceleration value is from all x, y and z axises, therefore the unwanted horizontal acceleration will affect the bumpiness reading, but usually it can be neglected due to its small value.

3.2.2 Real Time Charts

As shown in Figure 5, there are two charts in the measurement panel. The top one shows the real time acceleration readings for both x, y and z axises. The bottom chart has 3 data sets: acceleration difference (blue), bumpiness (red) and speed (orange). The speed reading (m/s) is determined by GPS, and please see section 3.2.1 for the meaning of the first two data sets.

3.2.3 Manual Mode

When in manual mode, you need to manually start and stop a measurement (Clicking START and PAUSE) and select the start and end point of the bump based on the waveform showing on the bottom chart (simply click on the chart), you can use the GPS reading for the speed as well as edit the speed manually and then click SAVE to save the data.

3.2.4 Auto Mode

In auto mode, the operations described in section 3.2.3 can be done automatically after you properly configure the settings. As seen in Figure 6, there is a switch to toggle between manual and auto mode, and the two threshold values can be configured there. It works as follows. Firstly, the threshold acceleration difference value (Thd in Figure 6) determines how sensitive the detection is and with the right amount, the start of a bump should trigger the detection while the flat road should not trigger anything. Secondly, the detection is only enabled when target bump is within a customizable distance (Dist in Figure 6). You can add locations very easily by clicking the EDIT BUMP button in the main profile panel, and then click the ADD BUMP button, enter a description and click ADD to add your current location to the database (Figure 7). Thirdly, the speed of the car is determined by the GPS and if the length of the bump plus the car is also known, how much time the car will spend on the bump can be calculated, which can be used to find the end of the bump.

$$Time_{OnBump} = \frac{Speed}{Length_{BumpAndCar}}$$

To get the length of the bump plus the car, you need to drive over a bump once, and manually select the start and end of a bump and then press the CALIBRATE button (Figure 6). Also a beep sound will be played if a bump is detected.

Because the GPS readings are always delayed and the pulling rate is low, the auto detection works well only if you keep the speed constant for a period of time before hitting the bump, which is difficult and dangerous to do so for speed higher than 20 km/h on King's College Circle[2].

4 Road Testing and Result

4.1 Test with Manual Mode

Road testing were performed on King's College Circle with a FIAT 500, and 12 samples were gath-

[2] Pedestrians frequently crossing the road

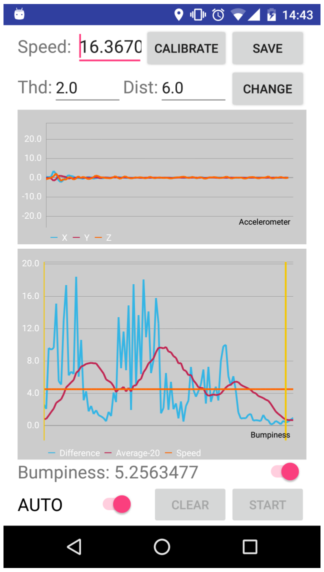

Figure 6: Auto Mode

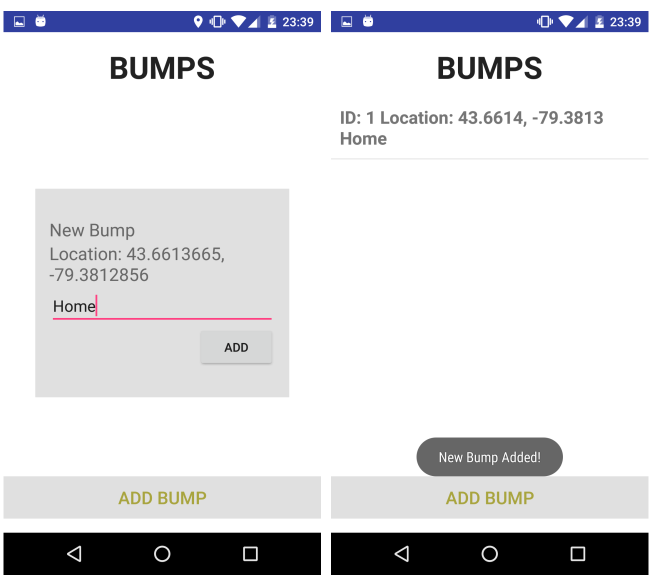

Figure 7: Add a Bump

ered for each speed range from 10 to 30 km/h. Only 4 samples for the 35 km/h, because there were pedestrians crossing the road frequently so at that speed it was pretty dangerous.

There are 7 speed bumps on the circle. Each time I drive over a bump I have to stop and store the data, therefore parking space are required. For speed below 20 km/h, all 4 bumps that have sufficient parking space are tested. But for higher speed, only the two bumps with long straight road before them are tested, since the car takes longer distance to reach higher speed.

4.2 Test with Auto Mode

The test ground is still at King's College Circle, but with a different car: Mini Cooper. And in addition to the 4 bumps mentioned in Section 4.1, one extra bump was tested, since parking space is not required for auto detection mode. It takes some time, however, to find the "perfect" threshold value settings. But once you set all the threshold values properly, as mentioned in 3.2.4, the auto detection works fairly well for speed lower than 20 km/h. Because you can keep the car speed constant before hitting the bump to accommodate the GPS reading delays and ultimately get a accurate measurement. However, when I trying to test higher speed, problems such as false detection and inaccurate speed emerged. Because of this, the test result for higher speed in auto mode is lacking.

4.3 Test Result

Figure 8 and 9 are the final speed vs bumpiness charts. Figure 8 is the result from measurement using manual mode, the other one is done by using auto mode. Because of the reason I mentioned earlier, the high speed data is lacking for the auto mode, but you can see similar trends on both plots. As you can see in Figure 8, the bumpiness value do fall after around 20 km/h and stays there. But keep it in mind that these values are independent of time, so the time you actually spend on the bump is shorter on higher speed, so the bumpi-

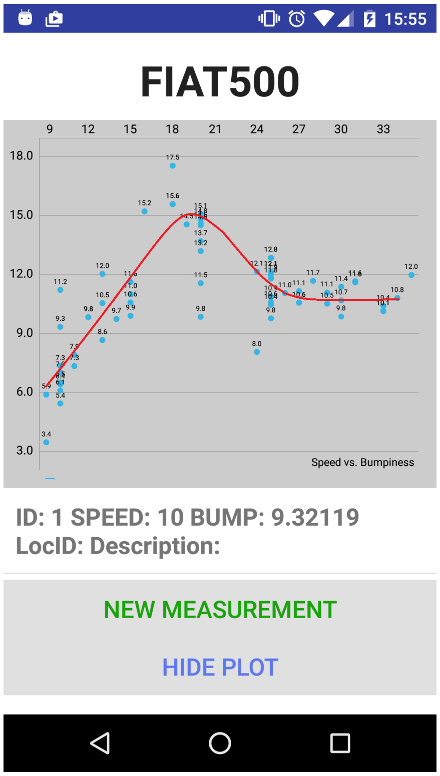

Figure 8: Manual Mode Test Result

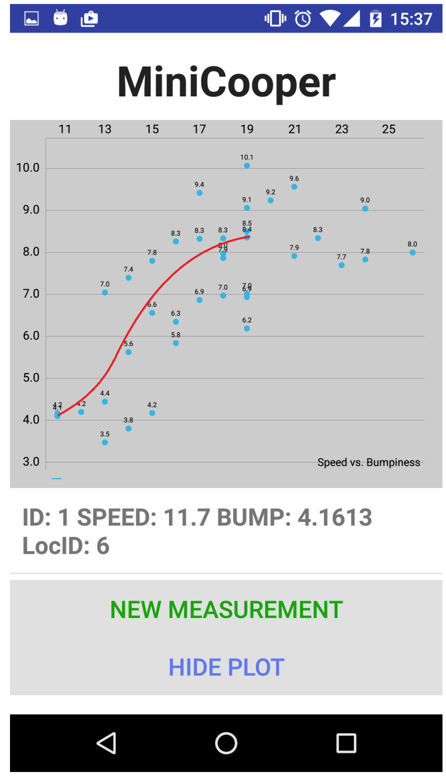

Figure 9: Auto Mode Test Result

ness you feel in general is actually smaller than the value. Another thing worth noticing is that the Mini Cooper has a better suspension system than the FIAT because the bumpiness readings at each speed are smaller.

So the conclusion is that the speed bumps on King's College Circle are indeed poorly designed, because a driver can simply drive over them with a speed higher than 25 km/h without slowing down and feel the same or even smaller bumpiness as driving over them at around 13 km/h. And from my observation during the road testing, a lot of drivers tend to not slowing down when encounter those speed bumps.

5 Key Learning

I have learned that testing is a very important part of the whole development process. In my case, the road testing revealed that the GPS accuracy is not sufficient for my application but I did not have any time left to modify the auto bump detection feature. What I should do was develop a rough prototype first and test it as soon as possible as a prove of concept so that I could have time to come up with a solution or entire different algorithm.

6 Future Work

Improving the auto bump detection so that it is less GPS dependent. Using data analysis instead of real time detection maybe the solution. Also adding more features such as map annotation that displaying the bumpiness values as colors on the roads.