Evaluating Sensors in Modern Smartphone to Damaged Road Features

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Abstract. The current modern smartphones have been equipped with multiple sensors to add the functionality of the phones. Two of the most significant sensors, accelerometer and gyroscope, are intended to sense the movement and orientation of the phone. We performed research to evaluate the capability of these two sensors to detect a road’s quality, which can be used to generate a map of road quality in a certain area. The research is done by placing the mobile phone in a flat area inside the car and ride the car through roads with various quality, especially the damaged ones. We collected the value of both sensors when passing through hollow, bumpy, and cracked roads with several variations of speed. Based on our test, we conclude that this method is not effective in detecting the quality of the road since it is hard to differentiate the data from other behaviours such as accelerating, braking, turning, or even the car vibration. In this paper, we present the method used to perform this research and the collected data that may help our conclusion.

1. Introduction
The use of smartphone application to collects information from users, usually called crowdsensing, is a common trend nowadays. With the availability of smartphone users everywhere, there are numerous of information and conclusion that can be gathered from the users. Additionally, most modern smartphone is already equipped with sensors that can be used to collect various types of data.

Smartphone as a traffic assistant is one of the trends in current society. Applications such as Google Maps, Waze, and Here are three of the main examples that are intended to aid traffic users to increase the efficiency of their travel. These applications can predict travel time by collecting information such as average user’s speed from their users. Another aspect that may affect travelling quality is the road condition. Damaged road surface may affect the efficiency of passing the road. Vehicles tend to accelerate and decelerate in these kinds of road. Additionally, passing through a heavily damaged surface may deteriorate the vehicle. Hence, this information may be useful for traffic users so they can find the most efficient way to get to their destination. Ability to collect such data and map it based on the location may be helpful to measure the quality of a certain part of the road.

In this paper, we observe the possibility of collecting these data by using the two sensors in modern smartphone, gyroscope and accelerometer. Our objective is to evaluate the accuracy of these sensors in detecting damaged road surface. To perform this evaluation, we build a simple Android based application that collects data from these sensors periodically while driving a car through a various types of damaged road surface. We then evaluate the data and conclude whether these two sensors are an effective tool to perform crowdsensing regarding damaged road features.
2. Related Works
The utilization of smartphone’s sensors as tools to expand the capability of an application is common in modern application. However, these sensors have limitation and how far this limitation affect the results is one of the main issues that need to be observed. There are numerous researches that tries to evaluate the capability of these sensors to achieve a certain objective. Blum et al. discusses the reliability of smartphone sensors in augmented reality applications [1]. The works focuses on the relativity of smartphone’s GPS and compass as navigating tools. The study was performed using Apple iPhone 4 and iPhone 4S which were launched in 2010 and 2011 respectively. Similarly, Mourcou et al. [2] evaluates the smartphone’s accelerometer and gyroscope and compare it with industrial robotic arms with an actual standard use inertial motion unit in clinical measurement, Xsens product. The result shows that built-in inertial sensors in smartphone are reliable for clinical field compared to standard tools.

Some researches focus on how software may increase the capability of the data received from the sensors. Ming Liu performed a study that evaluate the data from the sensor to achieve a specific information such as counting steps, analyzing drivers behavior, and sensing specific location based on environment ambient sound [3]. Purbandini et al. developed a software that maps landslide-vulnerable areas using smartphone [4].

There are also numerous previous researches focus on evaluating the use of smartphone’s sensors to aid traffic users. Johnson et al. developed an application that utilize sensors on smartphone to detect user’s driving behavior [5]. Similarly, Singh et al. developed an application that utilize mobile phone sensors to detect driving behavior [6]. The application is capable to detect turns, lane changes, sudden brakes/acceleration, and horns (using smartphone microphone). Kobana et al. [7] and Takahashi et al. [8] developed a road damage detection using smartphone for bicycle. Similar to our research, these two related projects are intended to collect sensors data from cycler’s smartphone and evaluate the data to mark road damages. Chen et al. developed Automatic Motorcycle Turn Signal (AMTS) which is aimed to assist motorcyclist to automatically signal turns based on the gyroscope sensor [9].

3. Sensors
In this research, we focused on two sensors that are available in most modern smartphone: accelerometer and gyroscope. In this section, we will have a thorough information regarding the sensors.

3.1. Accelerometer
Accelerometer is a sensor dedicated to detecting proper acceleration or the rate of change of velocity, which is the rate of acceleration of a body in its own instantaneous rest frame. In modern end-user devices such as smartphones and tablets, accelerometer are intended to detect device movement. While the gyroscope is intended to detect the device’s orientation, the accelerometer is intended to detect the movement so the orientation changes can be detected immediately.

3.2. Gyroscope
Gyroscope is a device intended to detect the orientation of a device. It consists of a freely-rotating disk called rotor, mounted in a spinning axis in the center of a larger more stable disk. Rotating the gyroscope will rotate the axis but the rotor, being affected by the gravity, remains stationary. Using this principle, we can find the orientation of the device relative to the earth gravity based on the state of the axis and rotor of the gyroscope. In modern smartphones, gyroscope is implemented by using microelectromechanical systems (MEMS) that is small enough to be inserted into a smartphone device.

4. Implementation
To achieve the purpose of this research, we built a smartphone-based application to be used to collect data from the street. The application is able to collect the gyroscope and accelerometer data and mapped it to a certain location. We also use Google Map feature to visualize the location where the data is collected. Figure 1 below shows the main UI of our application.
To collect the data, we first evaluate the affect of the car default vibration with the engine turned on and in both stationary and moving state. This data is important to exclude the noise generated during the test. Figure 2 below shows the data gathered from the accelerometer and gyroscope from these two tests.

The next tests series will be performed with the car moving through road features. We use three types of damaged road featured (shallow, deep, and minor surface deformation). Additionally, we also perform the test on a speed bump to see the capability of the sensors to differentiate hole and bump. We perform these tests on an empty streets; no other car or obstacles exists on the street. This condition is important to avoid the sensors affected by the deceleration of the car. Figure 3 below shows the types of road features that we included in our tests.

The first road features in our test is a shallow and wide hole. This type of holes is common due to its natural cause. Most of these holes are caused by the deteriorating quality of the asphalt due to lack of maintenance. In the first test, we passed the hole twice. In the first test, we travel through the hole with the velocity below 20km/h. In the second test, we passed the holw with the velocity above 40 km/h. In
both test, accelerometer and gyroscope shows an insignificant change when passing the road features. However, the second test (40 km/h) gives a slightly noticeable difference. When passing the minor surface deformation, both tests do not give any noticeable difference.

Additionally, we also collect the data when the car was passing a speed bump with 20 cm height and 30 cm width. The sensors, as shown on figure 4 below, able to gives a noticeable change when passing the speed bump and similar to the data from deep hole feature.

We also performed the test on a busy street to measure how the vehicle’s acceleration and deceleration affect the sensors. Based on our test result, the data collected is similar to the data from the deep hole tests: vehicle’s movement on a busy street gives a similar data to the movement when passing the damaged road features. In fact, further tests show that the data from vehicles on a busy street eclipses the data from the damaged road features that it is hardly possible to differentiate the difference between both data. The image below shows the test of the vehicle while passing damaged road features on a busy street.

5. Conclusion
We have successfully built an application to measure smartphone sensors in detecting damaged road features. We also have performed a series of test to evaluate the efficiency of the method. The first series of the test is performed in an empty street to minimize the noise made by the car movement. Based on the data we’ve collected, the sensors is capable to detect some damaged road features, especially the one with deep hole. The second series of the tests is performed in a normal-to-crowded road. The results on these tests shows that the noise caused by the car movement, mostly acceleration and deceleration, envelopes the data caused by the feature of the roads. Based on our observation, it is not possible to differentiate the data cased by the feature of the roads. Additionally, our tests shows that the data gathered from speed bumps are identical to the data collected from damaged road.

Based on these facts, we conclude that this method is not suitable to be used to collect damaged road data from end users. The noise generated from the car travelling through a normal traffic situation will envelope the data generated by the damaged road features. Moreover, most cars already equipped with
certain technology (notably the suspension) that capable to reduce the vibration of the car when passing uneven surface.

References

[1] J. R. Blum, D. G. Greencorn, and J. R. Cooperstock, “Smartphone Sensor Reliability for Augmented Reality Applications,” in Mobile and Ubiquitous Systems: Computing, Networking, and Services, vol. 120, K. Zheng, M. Li, and H. Jiang, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013, pp. 127–138.

[2] Q. Mourcou, A. Fleury, C. Franco, F. Klopcic, and N. Vuillerme, “Performance Evaluation of Smartphone Inertial Sensors Measurement for Range of Motion,” Sensors, vol. 15, no. 9, pp. 23168–23187, Sep. 2015, doi: 10.3390/s150923168.

[3] M. Liu, “A Study of Mobile Sensing Using Smartphones,” Int. J. Distrib. Sens. Netw., vol. 9, no. 3, p. 272916, Mar. 2013, doi: 10.1155/2013/272916.

[4] Purbandini, R. P. Pratama, and Susmiandri, “Application of GIS for the mapping of landslide-vulnerable areas by through android-based Analytical Hierarchy Process (AHP) method in Bantul Regency,” IOP Conf. Ser. Earth Environ. Sci., vol. 245, p. 012008, Mar. 2019, doi: 10.1088/1755-1315/245/1/012008.

[5] D. A. Johnson and M. M. Trivedi, “Driving style recognition using a smartphone as a sensor platform,” in 2011 14th International IEEE Conference on Intelligent Transportation Systems (ITSC), Washington, DC, USA, Oct. 2011, pp. 1609–1615, doi: 10.1109/ITSC.2011.6083078.

[6] P. Singh, N. Juneja, and S. Kapoor, “Using mobile phone sensors to detect driving behavior,” in Proceedings of the 3rd ACM Symposium on Computing for Development - ACM DEV ’13, Bangalore, India, 2013, p. 1, doi: 10.1145/2442882.2442941.

[7] Y. Kobana, J. Takahashi, N. Kitsunezaki, Y. Tobe, and G. Lopez, “Detection of Road Damage using Signals of Smartphone-Embedded Accelerometer while Cycling,” in Proceedings of the 2014 International Workshop on Web Intelligence and Smart Sensing - IWWISS ’14, Saint Etienne, France, 2014, pp. 1–2, doi: 10.1145/2637064.2637107.

[8] J. Takahashi et al., “Clustering for Road Damage Locations Obtained by Smartphone Accelerometers,” in Proceedings of the Second International Conference on IoT in Urban Space - Urb-IoT ’16, Tokyo, Japan, 2016, pp. 89–91, doi: 10.1145/2962735.2962741.

[9] B.-H. Chen, S.-K. Wong, and W.-C. Chang, “Motorcycle Ride Care Using Android Phone,” in Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA ’15, Seoul, Republic of Korea, 2015, pp. 1525–1530, doi: 10.1145/2702613.2732696.