Examination of Sensor Positions to Detect Bicycle Speeding Behavior

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Abstract. With the increasing number of bicycle riders, there is an increased risk of accidents between bicycles and automobiles. Some accidents are caused by speeding bicycles and the lack of communication between the cyclist and car drivers. To close the communication gap, we propose a method to detect speeding behaviors using a conventional smartphone. Using the smartphone, the cyclist will be able to obtain additional notification with minimum inconvenience and cost. We investigated the fundamental characteristics of accelerometer data with different mounting positions and shock absorber conditions. We found that the rear side position was the best for detecting speeding behaviors.

Keywords. Acceleration Sensor, Smartphone, Tablet, Bicycle, Accident Prevention, Rider Behavior.

1. Introduction

In Japan, the number of cyclists has recently been increasing, especially in urban areas. The major reason for this boom is increasing environmental and health awareness. In addition, the need for a self-propelled traffic method was again brought to the fore after the earthquake disaster on March 11, because many persons could not return to their homes in urban areas.

Even with this increasing trend, the bikeway in Japan are not sufficiently developed. **Table 1** shows the basic statistics of bikeways reported by [1]. In the absence of bikeways, bicycles have to travel along the side of the main road. If a car is parked on the side of the road, bicycles need to change lanes to avoid the car. If a car parking at the side of the road, bicycles need to change the lane to avoid the car. Moreover, the sudden exit of walkers or bicycles from the side of the road may lead to rapid and uncontrolled motion of bicycles. Such behaviors are dangerous especially when approaching a car from rear. Generally, cyclists should check the rear and control bicycles appropriately. However, in the case of such sudden events, there is no time for cyclists to check their rear. In this case, cyclists usually avoid accidents by braking or changing lanes. However, most bicycles are not installed with brake lamps, blinkers, as well as side/rearview mirrors. In any case, even with blinkers, there is usually no time to operate them. Therefore, a notification of the speeding behavior of bicycles should be presented in order to avoid accidents.

Table 1. Comparing of Bikeway Development

Country	Examined Year	The Bikeway's Extension (km)	Percentage of total length (%)	Per Land Area's Extension (m/km^2)	Per Bicycles Extension (m/1000unit)
Netherlands	1985	14,500	8.6	349	1,317
Germany	1985	23,100	4.7	65	660
Japan	2006	7,301	0.6	19	84

2. Related Works

Previous research regarding the detection of movement of two-wheeled vehicles can be placed in two categories: research using special devices and equipment and that using commodities such as smartphones and tablets.

Cossalter et. al. [2] presented and analyzed the dynamical measurements of several motorcycle crashes that were recorded both on the rider and the motorcycle using special devices. They collected gyrometer data, GPS measured acceleration, and roll angle. The data were intended to be used in implementing rider protection systems such as airbags. The approach used to detect the movement of a two-wheeled vehicle is the same, but they expected that the sensor devices are attached to both the rider and the motorcycle. We plan to introduce a safety system with more casual installation.

Tada et. al. [3] proposed a car driving behavior analysis method without installed sensors. By assigning small wireless 3D accelerometers to drivers, they could precisely capture drivers' steering control behaviors. They developed a method to detect bad motions of the drivers. The use of accelerometers to detect dangerous situations is similar, but we propose a method to improve the safety of bicycle riders using conventional smartphones.

Regarding the employment of commodity phones, Kamimura et. al. [4] proposed a motion detection system for motorcycles with a smartphone. They investigated noise reduction methods for data from the sensors, including not only accelerometers but also gyro sensors. Condro et. al. [5] proposed an active safety system of motorcycle with a Android smartphone. While the approach and motivation are similar, we investigate the motion detection of a bicycle that has less equipment than a motorcycle, such as brake lamps and blinkers.

To detect human behaviors, Kurasawa et. al. [6] developed a context-aware information platform that allows users to receive personalized information based on their context inferred by tiny sensors attached to their cellular phone. To improve inference accuracy, the system automatically detects the sensor position on the user's body. Bao and Intille [7] developed an algorithm that detects physical activities from five small biaxial accelerometers on the body. These studies aimed to classify human behaviors using accelerometer data, while we plan to obtain the speeding behavior of bicycles in order to prevent accidents.

3. Proposed Method and Approach

We consider that a notification mechanism is necessary to prevent accidents between bicycles and cars. To determine the notification mechanism, we propose a method to detect the speeding behaviors of bicycles. In this paper, we describe the method and present our fundamental examination of the proposed method. To detect the speeding behaviors of bicycles, several motion sensors need to be considered as accessories attached to the bicycle. However, attaching and detaching such sensors on the bicycle may be inconvenient for daily use. Moreover, the use of specialized devices for this purpose has limitations in terms of distribution. For these reasons, we propose the use of a smartphone instead of a specialized sensor. Smartphones are commonly used in daily life, and several models already possess motion sensors such as accelerometers and gyrometers. Owing to the lightweight and high portability features of smartphones, it is easily attached to the body of the bicycle.

Even though smartphones have high portability, the method used to install the device on the bicycle is important because the usability of the system depends on the installation method, such as its mounting position and the instrument used. As expected, the device should collect sufficient motion data to precisely detect speeding behaviors. Therefore, satisfying the constraints of daily usability and precise data collection is crucial for the system.

Before implementing the system, we decided to investigate the conditions regarding the mounting position that would satisfy the above constraints. The detection of bicycle speeding behavior is particularly difficult relative to motorcycle behavior owing to the instability caused by the pedaling action and lack of suspension mechanisms.

4. Preliminary Experiment

To determine the feasible mount position of the smartphone on a bicycle, we conducted a preliminary experiment. The purpose of the preliminary experiment was to examine the relationship between the mount position and acceleration data and to determine the best position for mounting.

4.1. Procedure

In this preliminary experiment, we employed a tablet (Apple iPad) instead of a smartphone as the sensing device. The reason for choosing the tablet was its stability; a large device is easier to fix to a bicycle. We captured the accelerometer data using Accelerometer Sensor Logger developed by REGREX Co., Ltd. The capture frequency was 3 Hz.

We considered three mounting positions: (1) front, (2) rear, and (3) rear side. As the first front position, we placed the device in the front basket connected with handlebars (see **Figure 1**). The merit of the front position was ease of installation for the rider. However, in the front mounting position, the accelerometer data are affected by the handlebars. As the second rear position, we placed the device on the rear carrier (see **Figure 2**). The mount position does not affect the movement of the handlebars. For the third rear side position, we placed the device besides the rear wheel (see **Figure 3**). The rear side position will be suitable for eliminating small movement that occurs when pedaling. For the first and second mount positions, we also explore the effect of a shock absorber. For the shock absorber, we employed an air bubble packing bag.

To obtain accelerometer data, we actually rode the bicycle under each mounting condition. The course was 130 meters long including three curves (see **Figure 4**) along with the 50m $\times$ 25m block. The speed while turning the first curve was 7 km/h, and the speed for the last two curves was 14 km/h. A single rider practiced riding at the same pace. The time duration of each ride was about one minute. Because the experiment focused on the investigation of fundamental data trends, we adopted the simple rounded course.

Figure 1. Mount condition: Front

Figure 2. Mount condition: Rear

Figure 3. Mount condition: Rear Side

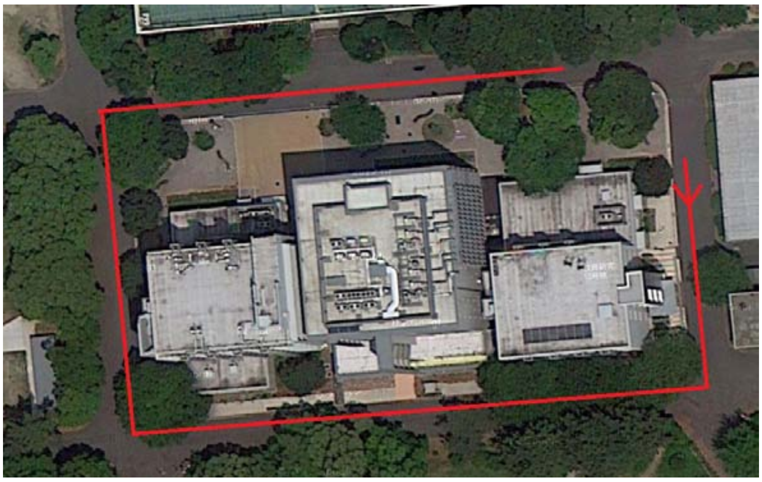

Figure 4. Experimental Course

4.2. Result

Figure 5 and **Figure 6** show the accelerometer data obtained without the shock absorber condition for the front and rear positions, respectively. The x-axis represents the captured accelerometer data number, and the y-axis indicates the value of the accelerometer data(m/s^2). The z data were affected by the gravity. The events involving the turning of the three curves were recorded at 55–65, 170–180, and 235–245, respectively.

Comparison of the two graphs reveals that the former data were noisier than the latter data because the movement of the handlebars influenced the accelerometer data for the front condition. Regarding the z data for the rear condition(**Figure 6**), we concluded that the rider's weight suppressed the vibration in the vertical direction. Because the z data should be utilized to detect the slight inclination of the bicycle, the vertical noise was not required. Thus, the rear condition has the advantage of eliminating minor movement.

Figure 7 and **Figure 8** show the accelerometer data with a shock absorber for the front and rear conditions, respectively. We compared them with the two former conditions without a shock absorber and no significant difference was observed. The possible reason was that the air bubble packing bag effectively reduced any impact, but it reflected the slight vibrations and did not moderate them. Note that the iPad cover itself has the ability to absorb slight shocks on the device.

Figure 9 shows the accelerometer data without the shock absorber for the rear side condition. In this mounting position, the x-direction of the device was affected by gravity; in other words, the device was mounted sideways. Therefore, the x-direction data should be utilized to detect slight inclinations of the bicycle in the condition. We observed that the x-direction data represent the significant value changes of 180–200 and 220–230, which are related to turning the second and third corners, respectively. However, turning the first corner did not cause significant changes. We consider that the bicycle was not slanted during the first turn because of the low speed. The noise level of the x-direction data was relatively low. A possible reason was that the position did not affect small swinging movement caused by the pumping pedal actions. To summarize these results, the rear side position was the best among the three positions, and the air bubble packing bag was inadequate for the suppression of the vibrations.

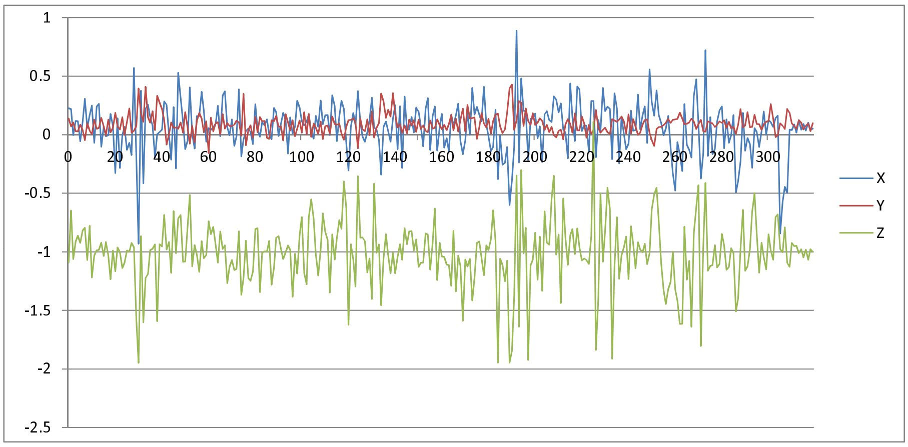

Figure 5. Accelerometer Data (Front, No shock absorber)

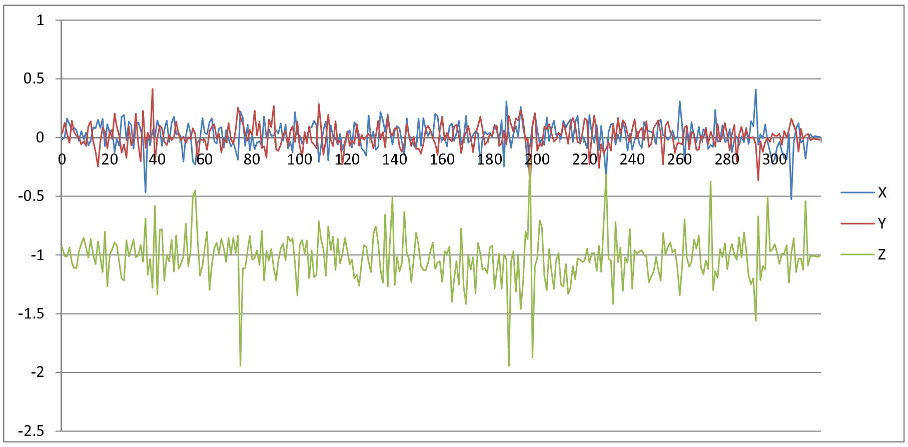

Figure 6. Accelerometer Data (Rear, No shock absorber)

5. Conclusion and Future Work

To prevent accidents that may occur owing to bicycle speeding, we proposed a method to detect the speeding behavior of bicycles using a conventional smartphone. Using the smartphone, the bicycle rider will be able to obtain additional information with minimum inconvenience and cost.

In our preliminary experiment, we investigated the fundamental characteristics of accelerometer data for varying mounting positions and shock absorber conditions. Our

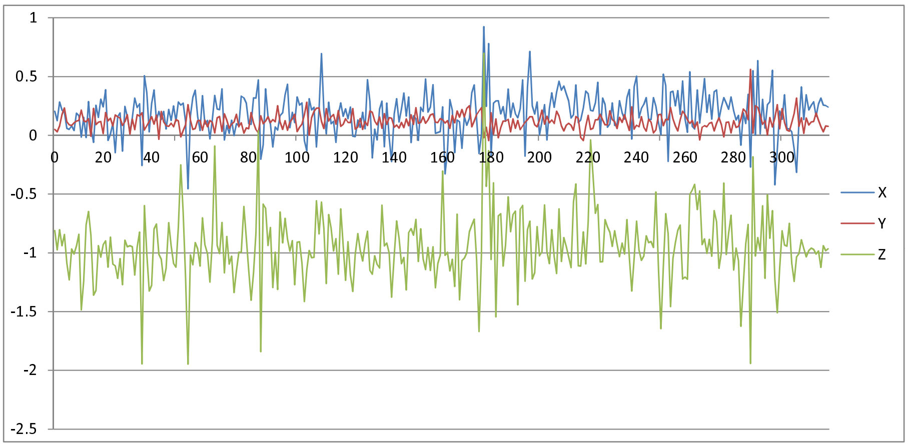

Figure 7. Accelerometer Data (Front, With shock absorber)

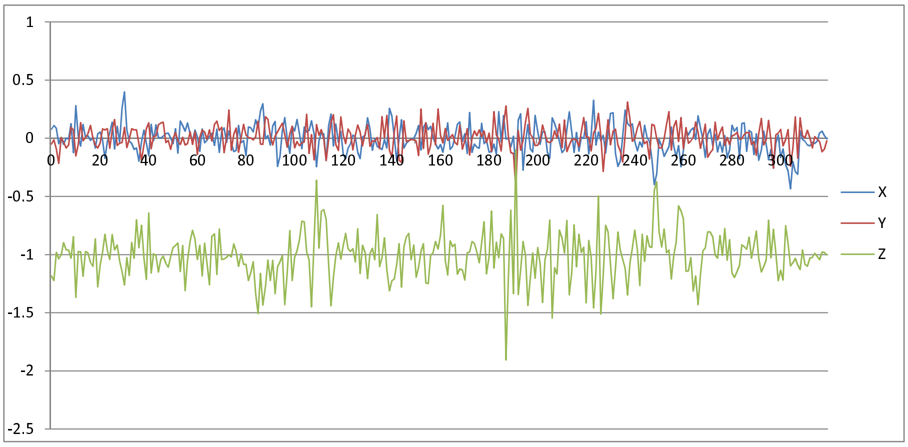

Figure 8. Accelerometer Data (Rear, With shock absorber)

conclusions were as follows: (1) the rear condition has the advantage of eliminating minor movement because the rider's weight suppressed the vibration in the vertical direction, (2) the rear side position was the best among the three positions, and (3) the air bubble packing bag was inadequate for suppressing vibrations.

As future work, we will examine the detection method based on our findings. Moreover, we will evaluate the feasibility of the method by implementing the proposed system.

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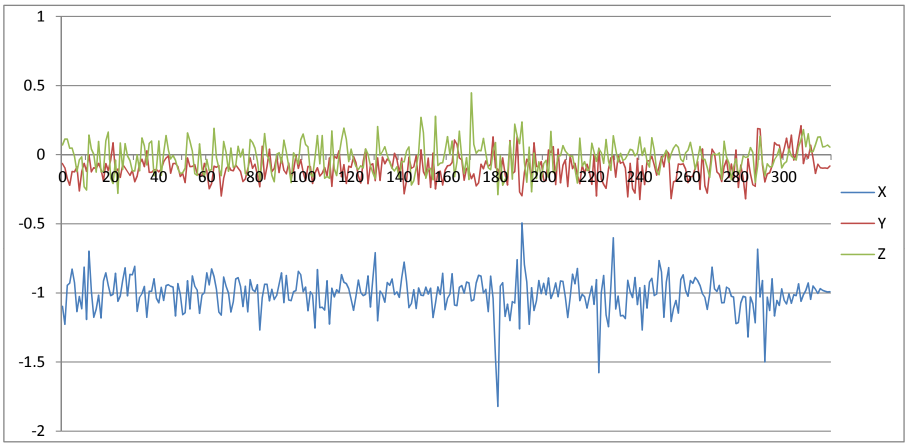

Figure 9. Accelerometer Data (Rear Side)

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