MotoSafe: Active Safe System for Digital Forensics of Motorcycle Rider with Android

Nowy Condro, Meng-Han Li, and Ray-I Chang

***Abstract*—Motorcycle accident rates have increased significantly year by year throughout the world. In this paper, we would like to introduce a motorcycle active safety system that can detect high risk riding states and decrease accident rates. As smartphone nowadays becomes a popular communication tools in society, we use smartphone as the platform of our system. By using sensors that equipped in smartphone, our system will do real-time monitoring based on data that obtained from those sensors and detect the high-risk motorcycle riding maneuvers. When high-risk maneuver is detected, our system will automatically alert the rider. An emergency message will be sent to police when the fatal accident happens. It can be a traffic data recorder with cloud computing to provide digital forensics information to police and insurance company for crash investigation. Our system has been implemented on Android smartphone and tested in real riding condition. Experiments show that data obtained from this system achieve high accuracy and precision.**

***Index Terms*—Active safe system, digital forensics, cloud computing, risk riding detection, smartphone.**

I. Introduction

Motorcycle becomes a popular transportation tools for various reasons. High mobility is the main reason why people choose to ride motorcycle in urban congestion. For some cities all over the world, motorcycle exempts from toll charge and parking fee. It has low maintenance cost. 200 million motorcycles use in worldwide or about 3.3 motorcycles per 100 people compared to 9.1 per 100 people for car [1]. In between 2000 and 2005, the motorcycle registrations have increased by 51% in USA [2]. Since motorcycle population has increased significantly year by years, it induces accident rate surged as shown in Fig. 1 [3]. In 2004, motorcycles have 16 times higher in serious injuries rate compared to cars for every million vehicle kilometers [4]. According to the U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA) report, 1.8 cars out of 10000, yet 5.58 motorcycles per 10000 ended up in fatal crashes in 2006. This result shows motorcycle has three times higher of crashes rate than cars [5].

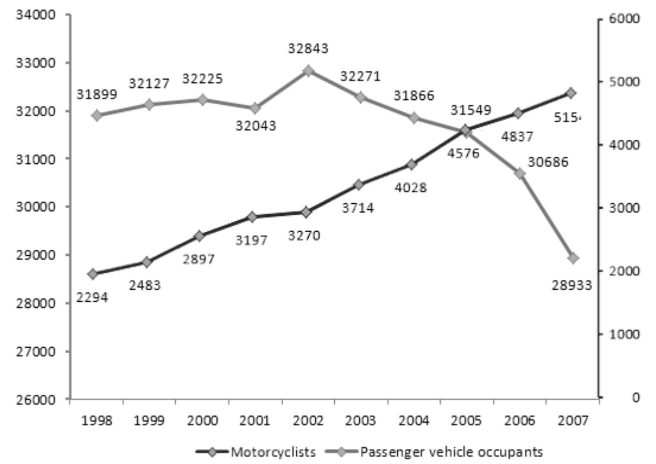

Fig. 1. Motor vehicle crash fatalities by vehicle type and year..

There was several driving monitoring research focusing on visual observation. They purposed various techniques to detect and track people's faces, eyes, facial expressions, etc. Moreover, charge-coupled device (CCD) cameras are required to acquire video images of the driver to implement these techniques [6], [7], [8], [9], [10]. In these techniques, accurate measurements of eyes, mouths, and other face parts are needed to obtain an optimal detection. Extra devices are also required. Some situations such as lighting and fast motion are more likely to increase the difficulty of these approaches. All of these techniques are not convenience and unrealistic to implement into motorcycle rider. In [11], [12], some of the patterns may be applied into motorcycle riding detection system. However, high-risk motorcycle maneuvers detection is more complex than dangerous driving detection. In the urban areas, motorcycle may have the weaving maneuver during traffic jam and have a high acceleration or deceleration more than car. Moreover, in the roundabout, motorcycle rider has a wide radius turning.

In this paper, we design and implement a system that can prevent high-risk maneuvers and decrease an accident rates that occurred by a bad motorcycle rider behaviors. With this approach, we offer a low-cost system that implement in Android, which become the fastest growing smartphone operating system on the world. Since smartphone is getting cheaper and widely used today, it makes smartphone not longer for calling or multimedia use only. Over 172 million unit smart phones were sold in 2009; it is almost 24% higher than 2008. Our system is designed to detect dangerous motorcycle maneuvers using sensors in smartphone, which comes equipped with sensors such as accelerometer, magnetometer, and GPS. It has implemented on smartphone, which has a high mobility. Without any extra hardware

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required, we purpose a high risk riding maneuver detection system for urban people using a common used device. This system not only enables to improve the common rider bad behaviors by making an earlier detection, but also can send an emergency alert when riders have a fatal accident in uninhabited areas.

Since current smartphone has its own communication module and has great display module, it can make an earlier detection and send an emergency report when a fatal accident is detected. Such a device becomes a great platform for the motorcycle active safety system. When high-risk maneuver is detected, our system will automatically alert the rider and sending an emergency report when the fatal accident happens. It can be a traffic data recorder with cloud computing to provide digital forensics information to police and insurance company for crash investigation. The summaries of our contributions are as follows.

- We design and implement the high-risk motorcycle maneuvers detection system on Android. It is lightweight, convenience, and no extra hard ware required.
- We conduct experiment with a dangerous and safety riding behavior. We observed different rider behavior to improve our system design and increase accuracy of our algorithm.
- Our system will automatically alert the rider if high-risk maneuver is detected. When the fatal accident happens, an emergency message will be sent to police.
- It can be a traffic data recorder with cloud computing to provide digital forensics information to police and insurance company for crash investigation.

II. Crash Investigation

The Organization for Economic Cooperation and Development (OECD) organize an experts group to develop a methodology to investigating motorcycle crashes. The OECD Common methodology has already been used in several countries. This methodology investigating crashes from a several factors: human factors that include the riding experience, licensing, training, drug, and alcohol use; motorcycle factors such as motorcycle condition, type, size, and handling characteristics; environmental details factors that consisting traffic controls, road condition, and riding circumstances [3].

Many factors of motorcycle crashes are human factors. Most common causes of motorcycle fatal crashes by human factors are as follows: riding a motorcycle while under the influence of alcohol; speeding; sudden braking or turning; failure to use defensive driving techniques; lack of basic riding skills; failure to use special precautions while riding [5], [13], [14]. In the 2008, speeding contributes 35% of the fatal crashes caused by motorcycle rider, compared to 23% for passenger car drivers. Also for fatal collision with a fixed object, motorcycle contributes the largest rate 25%, compared to 19% for passenger cars [13].

The most common of single-vehicle fatal motorcycle crashes is the failure to negotiate with proper turning curves. This type of crash usually cause by riding under influence of alcohol [15]. Moreover, riding motorcycle under influence of alcohol contribute a largest rate compared to other type of motor vehicles in 2008.

In a 60 km/h speed limit area, the risk of involvement in a crash victim doubles with each 5 km/h increase in moving speed above 60 km/h. Besides, the Australian National Health and Medical Research Council (NHMRC) Road Accident Research Unit recommended that to changing the urban area speed limit to 50 km/h on all roads to result in a reduction of at least 33 % in the number of free travelling speed casualty crashes [16].

III. System Design

A. System Overview

In this paper, we propose the dangerous motorcycle rider behaviors and traffic data recorder using smartphone and cloud computing. To archive our main idea, we present some patterns of high-risk motorcycle maneuvers: over speed, weaving with high speed, high speed sudden turning, *wheelie*, *stoopie* or sudden breaking. The dangerous riding maneuvers detection system is made up of three modules, the monitoring module, pattern matching module and alert module as describe in Fig. 2.

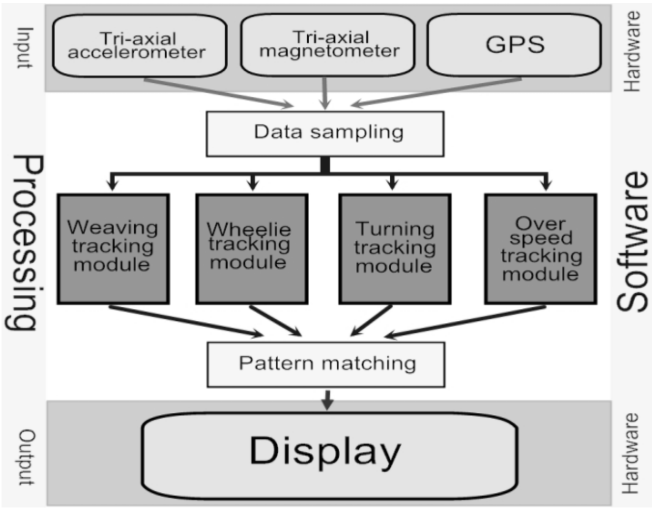
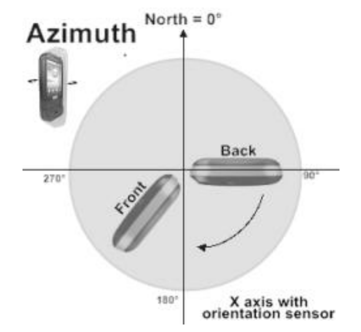
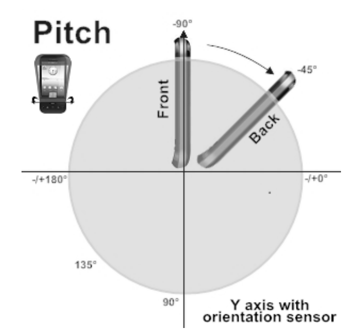
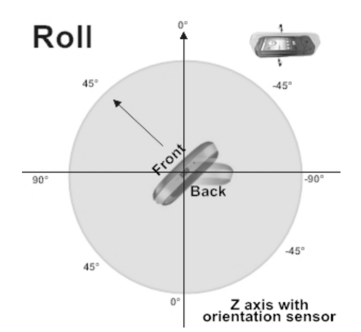


Fig. 2. MotoSafe system design.

Weaving riding in this paper and car weaving driving in [11] has a different pattern. The main differences are that motorcycle is allowed to ride in weaving pattern when facing a traffic jam. The high flexibility and mobility are the main reasons why most of peoples choosing motorcycle as they transportation tools in urban areas. Only in high speed, this weaving riding behavior is classified as high-risk maneuvers. This maneuvers detection method is using orientation sensor from *z* axis in Table I. Our system will calculate the angle changes in particular time to detect the weaving riding pattern. This high angle turning behavior detects by orientation

TABLE I: SENSOR MEASUREMENTS.

Axis	Maneuver	Measurement
x		Direction.
y		Acceleration, bumping, wheelie.
z		Turning, weaving, lean angle.

sensor described as *z* axis in the Table I. *Wheelie* is a vehicle maneuver in which the front wheel comes off the ground due to extreme torque applied to the rear wheel; the sudden braking or stoopie also induce the rear wheel come off the ground. These both behaviors are categorized as an extreme dangerous maneuver. This maneuver detect with *y* axis is shown in Table I. It is not more than $|30|^\circ$ of *y* axis in normal acceleration or deceleration in our investigation.

This system will alert based on the comparison between normal turning angle (Fig. 3) and other high-risk maneuvers as show in Fig. 4 and Fig. 5. There were accident occurred if the motorcycle *z* axis > $|75|^\circ$ and in a stop state. To use this system, the rider must mount his/her smartphone on the motorcycle before travelling. In the first start, this system will do adjustment based on the smartphone position, and start the real time monitoring after the ground speed is detected. This system will keep collect and record all the rider maneuvers data. Recorded data is uploaded to cloud using the Internet module that available in smartphone system. In the cloud, the recorded data is either use for personal or impersonal purpose. For the personal purpose, the recorded data is use to evaluate personal riding behaviors. This evaluate is to help motorcycle rider to improve their riding skill.

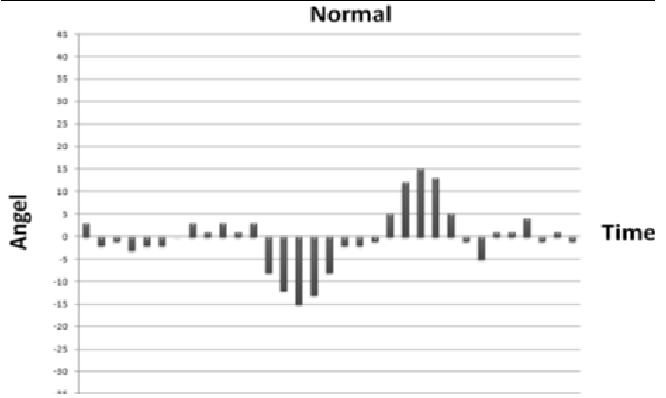


Fig. 3. Lean value in normal turning maneuvers.

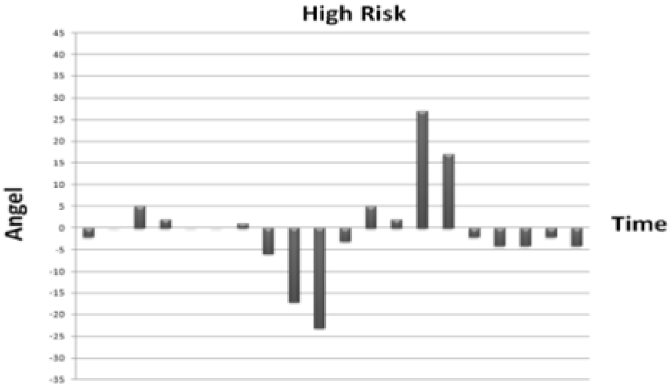


Fig. 4. Lean value in sudden maneuvers.

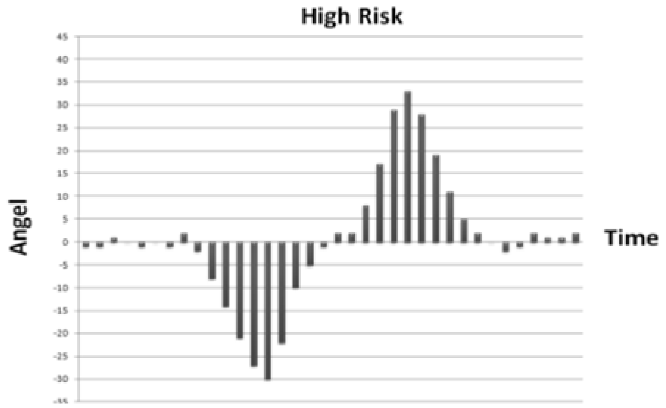


Fig. 5. Lean value in high angle turning maneuvers.

And for impersonal purpose, these data use for traffic condition report (e.g. traffic jam, road traffic volume), and for government road condition evaluation (e.g. bumping roads, dangerous road conditions, road planning). Moreover, these data also use to assist police and insurance company for investigation when accident occurred.

B. Implementation Design

We use accelerations sensor, magnetometer sensor, and GPS sensor, which are available in Android smartphone to implement this system monitoring module, as presented in Fig. 6. We use Tri-axial magnetometer sensor to detect the motorcycle position states. These angles are divided into *x*, *y* and *z* axis. The *x* axis in magnetometer sensor is to detect the direction of smartphone. It is known as Azimuth that is used in

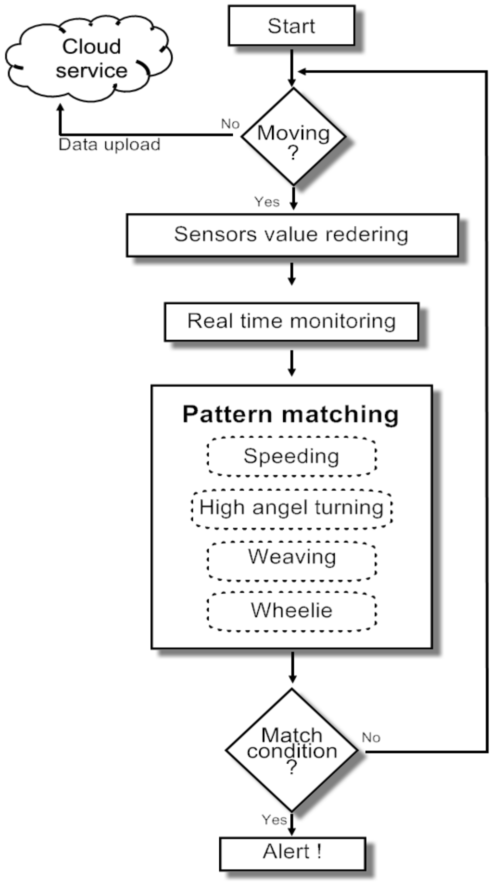


Fig. 6. Moto safe algorithm design.

many applications including navigation, astronomy, mining and artillery. This is usually measured in degrees. Azimuth value that have 0-360 degrees, where 0 or 360 represent north, and 90,180, 270 represent east, south, and west respectively.

The *y* axis detects the pitch angle of motorcycle. It represents the acceleration and deceleration of the motorcycle speed. To detect the current state, we first obtain the current of y axis value and the previous one, which denoted as θ_y and θ_{y-1} by (1):

$$S = \theta_y - \theta_{y-1} \ , \qquad (1)$$

where negative S represents speed acceleration and positive S represents speed deceleration.

We use *z* axis value from magnetometer to obtain the roll values that represent the lean angle of the motorcycle. The *z* axis > 0 represent right turn and *z* axis < 0 as left turn. In the real detection, we will remove noises that received from the unpredictable factors, such: engine vibration, road condition, rider movement, etc.

For the speed detection, we use GPS sensor to render motorcycle position based on latitude and longitude. These values are good to calculate ground speed of the motorcycle. Combine the *z* axis and speed; we calculate the angle of lean θ using the laws of circular motion:

$$\theta = \arctan(s^2 / g * r) \ , \qquad (2)$$

where *s* is the forward speed in meter/second is, *r* is the radius in meters and *g* is the acceleration of gravity (a constant value 9.81).

Fig. 7. Motorcycle lean angle.

We use 50 *km/h*, speed limit that recommended by NHMRC Road Accident Unit in the urban area, and 12 feet for the standard road width to determine the maximal value lean angle for motorcycle. Using (2), we obtain the maximal lean angle in turning is around 34°. Besides, in [17], 30° is defined to incipient fall event of the motorcycle fall event. Therefore, we use 30° is our maximal limit of turning behavior.

The system is unable to use the acceleration sensor to detect the motorcycle maneuver because of the noise from motorcycle engine vibration. The only possible situation to use the accelerations sensor is when the motorcycle has a serious collision with a fixed object. Therefore, we use the magnetometer to detect motorcycle maneuvers. This magnetometer has three parameters. We use M_x, M_y and M_z to represent those values respectively. The M_y value is used to determine the longitudinal acceleration of the motorcycle. It ranges from negative 180 to positive 180, where zero represent the default angle when this system starting. When the abnormal acceleration or deceleration maneuver occurred, all these maneuvers detected from this value. The M_z value has a main role to detect most of motorcycle maneuvers. The weaving and high lean angle turning as shown in Fig. 7 is the most common motorcycle maneuvers that easily detected from this value.

The pattern matching we use in this system as described in following:

1) *Speed pattern matching:* The speed value obtained from the GPS sensor by using *Location.getSpeed()* that provide by Android API. The actual calculation are from (3); where ϕ_s, λ_s; ϕ_f, λ_f are the latitude and longitude of two points and $\Delta\lambda$ represent their differences and combine distance and time to get the accurate ground speed. This value not only detects the ground speed of the motorcycle, but serious crashes. We assume there are serious crashes when the speed has a zero value with an extreme accelerometer and magnetometer values obtained.

$$D = radians(ar\cos(\sin\phi_s \sin\phi_f + \cos\phi_f \cos\Delta\lambda)) \qquad (3)$$

2) *Angle pattern matching*: Based on *z* axis in Table I above, we detect the lean angle of motor cycle. The lean angle use to determine motorcycle maneuvers and doing pattern matching that consist weaving, high angle turning and sudden turning. Due to the extreme acceleration or deceleration of the motorcycle, this system detects these maneuvers with y axis that is described in Table I.

3) *Accident pattern matching:* In the real riding condition, the extreme accelerometer values represent the bad road condition, collision with moving or fixed objects, or the accidents occurred. For the bad road condition, this system will decrease the sensitivity and increase the time period to get sampling data of angle pattern matching. Noise from the bad road condition can be reduced by this approach. Since motorcycle contributes the largest rate for fatal collision with a fixed object compared to passenger car, we also design a system that will send an emergency report when fatal accident is detected.

IV. Implementation Result

We use Android developed by Google for our system's platform. Android is a mobile operating system based on a modified version of Linux kernel. Android widely used for other devices in present market, such as mini laptop, tablet pc. Android provides GUI SDK tools that allow developer to design the application GUI and write in the Java language. Current prototype is deployed on Android 1.5 Magic manufactured by HTC. It features a Qualcomm ARM processor with 288 MB RAM. The prototype implemented in Java that consists of 4 classes, which includes one Activity class, one *TimerTask* class and two View classes. The main components of this prototype divided into five parts: user interface module, sensor listener module, pattern matching module, traffic data recorder module and the notification module.

In the real detection process, the position adjustment value determine from how the user mount the smartphone onto motorcycle. This induce smartphone has different angle position due to different user. We use Velcro stripe to mount smartphone onto motorcycle as show in Fig. 8. This system obtains the smartphone position before the monitoring is run and doing adjustment to get the accurate value. The pattern matching module will keep reading the data obtained from sensor listener module. It will show an alert in the screen when the dangerous maneuvers are detected. This alert show a different color based on the dangerous level such as green color for normal condition, blue color for low risk condition, yellow color for high risk and red color for dangerous condition.

Fig. 8. Device position on motorcycle.

User may choose to turn on or turn off the notification module in the configuration settings. This notification module will send an emergency alert when the fatal accident is detected. When stop condition is detected, this system will upload the collected data to Cloud.

We designed the *MotoSafe* user interfaces with large display. No confusing features, clear option and simple display. Running in full screen making accessible display when the user riding the motorcycle. The menu contains four options: *start*, *stop*, *roll view*, *pitch view*, and *exit*.

V. Conclusion and Future Works

In this paper, we present the system that provides solution to reduce motorcycle accident rates in the urban area. Without any extra device, we use smartphone to develop dangerous detection system for motorcycle rider. By attaching smartphone to motorcycle, our system collect, record, and analyze all data from sensors to detect any high risk riding maneuvers. In future work, we will expand our high risk detection system and traffic data recorder not only for motorcycle, but also for car, bicycle, walking. Our work extension services are including government and public services.

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