Sensing Phone Use of Motorcycle Drivers

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\textbf{Abstract}—Due to safety reasons, using mobile phones while driving is prohibited in many countries. Research has also shown that motorcycle riders are 20 times more likely to be killed in a crash than vehicle occupants. Therefore, it is more critical to restrict the use of mobile phones of motorcycle drivers than car drivers. There are some studies that focus on how to distinguish phone use between a driver and other passengers in a car. The techniques used for cars, however, are not always applicable to motorcycles. In this paper, we propose a way to detect phone use of motorcycle drivers. By using two low-cost Bluetooth emitters, mobile phones of the driver and the passenger can measure the signal strengths and decide their locations. We have conducted extensive experiments with various smartphones. The results show that on average we can achieve 96\% accuracy.

\textbf{Index Terms}—Driving safety, sensing driver phone, smartphone, motorcycle, scooter, Bluetooth, location classification

I. INTRODUCTION

According to Governors Highway Safety Association, mobile phone use and texting are two of the most common distractions for drivers which associated with many automobile accidents [1]. A study done by Virginia Tech Transportation Institute also shows that sending or receiving a text takes a driver’s eyes away from the road for an average of 4.6 seconds. This equates to driving blind over the length of a football field at 55 mph [2]. Another study done by National Safety Council shows that 21 percent of crashes or 1.1 million crashes in 2010 involve talking on handheld and hands-free mobile phones, and an additional 3 percent or more crashes or a minimum of 160,000 of crashes in 2010 involve text messaging. Due to safety reasons, it is prohibited to use mobile phones while driving in many countries now [3]–[5]. Although using a hands-free phone while driving is allowed in some countries, studies have indicated that using a hands-free phone while driving is not necessary to be safer than using a handheld phone [6]–[8]. In order to enforce the laws related to mobile phone use, there are some technical approaches that focus on how to distinguish phone use between a driver and other passengers for four-wheel motor vehicles\textsuperscript{2} so the use of driver’s phone is restricted automatically [9], [10].

Although there are some solutions which may detect and restrict mobile phone use automatically for cars, those solutions are not applicable to two-wheel vehicles including mopeds, autobikes, scooters and motorcycles\textsuperscript{2}. Research has indicated that motorcycle riders are 20 times more likely to be killed in a crash than car occupants [11]. According to the research note of the National Highway Traffic Safety Administration, U.S. Department of Transportation, there were 4,469 motorcyclists killed and 90,000 injured in traffic crashes in 2009 [12]. There were 4,502 killed and 82,000 injured in 2010 [12]. In Taiwan, approximately 67\% of the registered vehicles are scooters and motorcycles. An average of 1.5 persons owns one scooter [13], [14]. Statistics also shows that more than 91\% of injuries and more than 79\% of deaths in traffic accidents are contributed by those involving scooters [15]. Experiments indicate that both texting and phone use while driving are as dangerous as drunk driving [16], [17].

It may not easy for people living in a country without many motorcycles to imagine how to use mobile phone when riding a motorcycle. A common way is to use one hand to hold the phone to the ear with the other hand on the handgrip to control the motorcycle. The other way is to cradle a phone between the head and shoulder. Some people even insert the phone into helmet so the helmet functions as a hands-free phone holder as shown in Fig. 1. For texting and browsing Internet, a most common way is to drive with one hand and use the other hand to operate the phone. Some people even can use two hands to text while still driving. A real case happened in Austria as shown in Fig. 2 which is from the news in [18]. The rider was caught on video [19] and lost his license due to this dangerous behavior. Because it is extremely dangerous, it is illegal to use a hand-held or hands-free mobile phone while riding a motorcycle in many countries [5], [20], [21].

There are some solutions which may detect and restrict mobile phone use automatically for car drivers. However, motorcycles and cars are different in many ways. Specifically, we consider that there are two seats at most in a motorcycle while there are four seats or more in a car. A common way to prohibit phone use is to determine whether the motor vehicle is moving by using Global Positioning System (GPS) or other means [22], [23]. Once the speed is over a certain threshold, an APP in the phone then block incoming/outgoing calls, texts, and other messages [24]–[28]. Most of the products in the market use this technique. This approach, however, cannot distinguish driver’s phone and passenger’s phone. It will block the phone use of the driver and all passengers. A most notable solution is to use the left and right (and if possible, front and rear) speakers in cars to determine which car seat a phone is being used [9]. The solution is not applicable to motorcycles because most motorcycles do not have any speaker. In addition, its successful rate is only around 90\%. There are also other techniques proposed for this problem [10].

\textsuperscript{1}In this paper, we use \textit{cars} as a generic term for all types of four-wheel motor vehicles, such as sedans, vans, trucks, and buses.

\textsuperscript{2}Thereafter, we use \textit{motorcycles} to represent two-wheel motor vehicles including mopeds, autobikes, scooters and motorcycles discussed in this paper.
II. DESIGN CHALLENGES

Our main purpose is to detect the mobile phone use of the motorcycle driver without affecting the passenger. In this section, we delineate the major challenges for our design.

1) The first challenge is that the driver and passenger are very close to each other in a motorcycle. We measured the seat length of various types of motorcycles and scooters. The average length from two far ends of driver seat and passenger seat is around 63 cm. If we adopt a position technique [30]–[33] to solve the problem, it must be able to achieve an accuracy less than 63 cm. It is well understood that GPS cannot achieve such accuracy. Some positioning techniques may meet the requirement. However, they are either too expensive or not applicable to motorcycles.

2) A driver and passenger may put the mobile phone in different places, for example in the pocket of shirt or pants. Fig. 3 (c) illustrates that a phone may be put in positions E, F, G, H, I. The solution must be able to work correctly no matter where the driver and passenger put the phone.

3) A two-wheel motor vehicle usually is much cheaper than cars. This is especially true for scooters. A new daily-used scooter in some Asia countries can cost as low as $1,000 US dollars. It does not make sense to adopt the techniques which require expensive equipment. Therefore, the solution must be cost-effective.

4) The solution must be simple and easy to deploy. It should be unobtrusive and should not change the appearance of the motorcycle. Especially, it should not increase the size of the motorcycle. For instance, installing multiple speakers in the front and rear of a motorcycle [9] or a specialized antenna [10] is not preferable.

III. SYSTEM DESIGN

In this section, we present our design. Although there are many challenges, we manage to come out a very simple, cost-effective, and accurate solution.

Our ultimate goal is to distinguish driver’s phone and passenger’s phone. It is not to calculate the distance between the two phones. In addition, driver’s phone and passenger’s phone may be carried differently as discussed earlier. Therefore, we do not adopt the positioning and localization techniques [30]–[33]. Our solution is very simple. We only install two BT emitters in the front and back of the motorcycle as that shown in Fig. 3 (a). The BT emitter provides the information including BT ID and Received Signal Strength (RSS) which enables the APP in the phone to decide whether the phone is in driver’s position. If the signal strength received from the front BT emitter is higher than the signal strength received from the back emitter, it is a driver’s phone. Otherwise, it is a passenger’s phone.

To make the signal strength in passenger seat lower, our technique is surprisingly simple. Our insight is that we use human body as a signal-blocking obstacle. People are actually quite good at blocking BT signals. Human body does a great job in absorbing radio waves at the frequencies used by BT because water constitutes around 60% of the human body [34].
Therefore, the useful range of the BT emitter will be reduced. In our design, we use the driver as the block obstacle. Thus, the problem is solved easily.

Intuitively, we can install only one BT emitter in the front of the motorcycle to achieve the same purpose. However, the phone will receive only one signal and won’t be able to make a proper decision. Although the RSS measured in driver’s phone generally will be higher than that in the passenger’s phone, it is hard to find a clear cut point to distinguish driver’s phone and passenger’s phone. This is because most likely the driver and passenger will carry different phones made by different manufactures which use different BT receivers. At the same position, different phones may measure different RSSs from the same BT emitter. Therefore, no proper RSS threshold enables the APP to correctly make a decision. We conducted extensive experiments by using only one BT emitter and concluded that using one BT emitter is not enough. Due to space limit, we do not show the results here.

IV. ANALYSIS OF BT LOCATION

The main goal of the design for the two BT locations is to provide two different patterns for the driver and the passenger through the RSS and the BT ID. The RSS introduced in [35] can be modeled by the electromagnetic propagation model as $S_{RX} = E_0 \frac{\lambda}{4\pi d^2}$ where $S_{RX}$ is the signal strength at the Receiver $RX$, $E_0$ is the signal strength at the Transmitter, the wavelength $\lambda$ is equal to 12.5 cm for BT frequency band, and $d$ denotes the distance between the transmitter and the receiver. Specifically, we denote the RSS for $i$-th BT Transmitter at the phone of Driver as:

$$S_{D,i} = E_0 \frac{\lambda}{4\pi d_{D,i}}$$  \hspace{1cm} (1)

where $d_{D,i}$ is the distance between the phone of the Driver and the $i$-th BT Transmitter. Similarly, the RSS for $i$-th BT Transmitter at the phone of the $j$-th Passenger is denoted by:

$$S_{P,j,i} = E_0 \frac{\lambda}{4\pi d_{P,j,i}}.$$  \hspace{1cm} (2)

where $d_{P,j,i}$ is the distance between the phone of the $j$-th Passenger and the $i$-th BT Transmitter. Based on above, the RSS will decrease when increasing the distance between the BT Transmitter and the Phone. We exploit the RSS model to analyze the two BTs in the motorcycle with one driver and one passenger (i.e., $i \in \{1, 2\}$, and $j = 1$).

Now we consider the standard vehicle model, and the phone positions for Driver and Passenger are shown in Fig. 3 (c) denoted by E, F, G, H, and I. Two BTs, denoted by BT1 and BT2, are set at the front and back of the motorcycle. The RSSs corresponding to the driver and the passenger are shown in Fig. 4 and Fig. 5, respectively. The two RSSs corresponding to BT1 and BT2 are set with positions E and F and are computed by Eq. (1). The results are shown in Fig. 4. As shown in the figure, the RSS measured for BT1 is always higher than the RSS measured for BT2. On the other hand, Fig. 5 shows the results for positions G, H, and I by using Eq. (2). The RSS of BT1 is never greater than that of BT2. Based on the analysis, a phone can decide whether it is in driver’s position by measuring the RSSs of BT1 and BT2. In addition, all phones can make the decision independently.

V. EXPERIMENTAL RESULTS

We use two HL-MD08R-C2A BT emitters to conduct our experiments. The HL-MD08R-C2A supports complete 2.4 GHz radio transceiver and baseband. Moreover, it supports BT Class 2 with operation up to 10 meter range. A BT emitter
A, the experimental results show that not all of the received results are shown in Fig. 7. Similar to the results at point B, the decrease in RSS from the front BT emitter is stronger than that from the back BT emitter. As shown in Fig. 6, however, we there is a driver on the motorcycle, as shown in Fig. 3 (b). We then present the results that automatically. The phones we used in experiments are listed in Table I. Coming phone calls will be directed into voice mail if it is in passenger on the motorcycle, as shown in Fig. 3 (c). We then present the results that there is a driver on the motorcycle, as shown in Fig. 3 (b). Finally, we demonstrate the results that there are a driver and a passenger on the motorcycle, as shown in Fig. 3 (c).

A. No Driver and Passenger: Point A

When the smartphone is located at point A, the RSS measured from the front BT emitter should be stronger than that from the back BT emitter. As shown in Fig. 6, however, we can see that in some cases the received signal from the back BT emitter is stronger than that from the front BT emitter. This is because the distance is too short. The decrease in RSS is not that significant.

B. No Driver and Passenger: Point B

At point B, there is still no person on the motorcycle. The results are shown in Fig. 7. Similar to the results at point A, the experimental results show that not all of the received signals from the back BT emitter are stronger than those from the front one. Sometimes it is hard to distinguish where the smartphone is. The results in Fig. 6 and Fig. 7 also show that generally can be bought at the price less than $3 US dollars. In the smartphone, we implement an APP which first uses GPS to decide whether the phone (motorcycle) is moving. If it is, the APP will then measure the RSSs to decide the phone’s position. If it is in driver’s position, communications including phone calls, text messages, and Internet access are blocked. Coming phone calls will be directed into voice mail automatically.

### Table I

<table>
<thead>
<tr>
<th>Smartphones Used in Experiments</th>
<th>Android Version</th>
<th>Linux Kernel</th>
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<td>Sony Xperia Lt26i</td>
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</tbody>
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**Fig. 6.** Average RSS measured at Point A

**Fig. 7.** Average RSS measured at Point B

**Fig. 8.** Average RSS measured at Point C

**Fig. 9.** Average RSS measured at Point D
different phones perform differently at the same position. This is because each phone has different BT hardware and driver. This also reflects our statement in Sec. III that using only one BT emitter cannot always distinguish the phone’s position.

C. Driver Only: Point C

Because the back BT signal is blocked by the driver at point C, we can see that all of the results indicate that the RSS from the front BT emitter is stronger than that from the back BT emitter as shown in Fig. 8. The correct rate to detect a phone’s position in a longer time scale is listed in Table II. On average, we have 98.75% correct rate for the experiments here.

D. Driver Only: Point D

Fig. 9 illustrates the results for the phones at point D. Still, the back BT’s signal is blocked by the driver so the results show that the received signal from the front BT emitter is stronger than that from the back one. The correct rate of each phone in a longer time scale is also listed in Table II. In this test, we have 100% correct rate.

Comparing the results in Figs. 6–7 and Figs. 8–9, we can see that human body is a good signal-blocking obstacle.

Next, we turn our attention to the results when there are a driver and a passenger. We conducted our experiments with the phones put at positions E, F, G, H, and I, as indicated in Fig. 3 (c). Due to space limit, the results for positions E and F are only shown in Table II. They are similar to those at positions C and D.

E. Driver and Passenger: Point G

Fig. 10 and Table II show the results when the smartphone is located at point G. Because the phone is in-between the driver and the passenger, both the front and back signals are blocked. The results indicate that the SONY Xperia LT26i and HTC SENSATION only have 60% and 55% correct rate, respectively. However, the other two phones have near 100% correct rate. We think the reason is that the antenna design of different BT modules is different. We plan to test more phones and provide a list of the results so users can choose a phone with good performance. If there is a law to prohibit phone use when driving, the government can list the requirements of the BT module in a phone and enforce the manufactures to comply with the requirements.

F. Driver and Passenger: Point H

When the phone is put at point H, the signal of the front BT is blocked by the driver and the signal of the back BT is blocked partially by the passenger. Fig. 11 shows the experimental results. Table II indicates that the correct rate is 96%.

G. Driver and Passenger: Point I

At point I, the front BT signal is blocked by both the driver and the passenger. Moreover, the phone is very close to the back BT emitter. Fig. 12 shows that in general it is easy to decide that it is passenger’s phone. Table II indicates that the correct rate is 99%.
In summary, our proposed solution has 99.375% correct rate when there is only a driver on the motorcycle. When there are both a driver and a passenger on the motorcycle, our method have 94.25% correct rate. In all of our experiments, the average of correct rate is 95.71%.

VI. SUMMARY

Although there are some techniques proposed to distinguish driver’s phone and passenger’s phone in cars, they are either too costly or not applicable to motorcycles. For example, a recent study presented in [9] needs to use the left and right (and if possible, front and rear) speakers. Still, its correct rate is only around 90%. In this paper, we propose a very simply but effective way for motorcycles. We only need two BT emitters which are very cheap. On the other hand, we can achieve 95.71% correct rate.

VII. ACKNOWLEDGMENTS

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