Mobile Traffic Accident Prevention System based on Chronological Changes of Wireless Signals and Sensors

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Abstract

With the recent developments of ITS, it is expected that the traffic accidents by vehicles are decrease in the future. However, it is necessary to consider the traffic accidents for bicycles and pedestrians as well as vehicles. Therefore, this paper proposes the mobile traffic accident prevention system based on the chronological changes of Wireless and Sensors. The proposed systems continuously observe the radio signals and multiple sensors on the mobile devices, and the observed values are categorized into two types of sensors such as the sensing of the dangerous smartphone's operations and the rapid approaching vehicles or bicycles. Then, the proposed algorithm based on the Markov Chain algorithm is introduced to identify the dangerous conditions. Moreover, the implementations of the prototype system are shown in the paper, and the field experiments of the WiFi detection of the proposed methods are discussed for the effectiveness and the future studies.

Keywords: Traffic Accident Prevention System, ITS, Sensors, Markov Chain Process

1 Introduction

With the recent developments of Intelligent Transport System (ITS) such as the autonomous vehicles or vehicle-to-vehicle (V2V) communication system, it is expected that the traffic accidents are decreased in the near future. In fact, there are some researches or merchant services to reduce the traffic accidents by the usage of the GPS locations or the V2V communication in the vehicles. However, it is important to focus on the bicycles or pedestrians as well as vehicles in case of the traffic accidents in recent.

For example, the car driver played the AR smartphone's game during the driving, and he killed two women by the traffic accident in Tokushima, Japan [1]. Moreover, was hit by the truck driver hit the elementary student in Aichi, Japan [2], and these accidents causes the serious discussions about the morality of playing the famous AR game in the town in Japan. Moreover, many prefectures in Japan including Tokyo [3] now enforce the regulation against the bicycles with the operating smartphones because of the great number of the bicycle's accidents.

Concerned with the traffic accidents including vehicles or pedestrians, it is supposed that the usages of the mobile devices such as smartphones are very effective methods because most of people carry and easy to use smartphone recently. Besides, smartphone equips wireless interfaces and sensors. Therefore, this paper proposes the mobile traffic accident prevention system based on the chronological changes of wireless and sensors on the mobile phones [4]. The purposes of the proposed methods are to sense the

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dangerous smartphone operations during driving vehicles or bicycles, and to detect the rapid approaching objects even if the LTE or 3G networks are disconnected in the local areas. Thus, the mobile devices continuously observe the wireless signals and multiple sensors on the mobile devices, and the observed values are calculated by the Markov Chain algorithm in the proposed systems.

In the followings, the chapter 2 shows the related studies of the traffic accident prevention system, and the chapter 3 deals with the proposed methods using the chronological changes of wireless and sensors on the mobile phones. Then, the prototype system is explained in the chapter 4, and the experimental results are discussed in the chapter 5. Finally, the conclusions and the future studies are explained in the chapter6.

2 Related Studies

In general, the recent researches of the traffic accident prevention systems introduces the GPS locations and V2V [5] [6] or the vehicle-to-everything (V2X) networks [7]. For example, the previous paper [8] proposed the V2X alert communication system by using the proposed map-matching approaches with the GPS sensors on the smartphone, and it especially assumed the system between the vehicles and the visually handicapped persons. The paper [9] also introduced the mechanism to warn approaching bicycle and pedestrians in both by using GPS locations from smartphones. Although the only GPS data was not effective, but the paper evaluated the appropriate distance for warning by the experiments, and the proposed threshold values with the error range modification are presented for the effective safety system. Besides, Toyota already started such a safety system called the ITS connect system [10]. The ITS connect is the driver support system connected by the 760MHz radio band between vehicles and fixed stations such as the traffic lights or telegram poles, and the GPS locations are transmitted to each other in order to provide the notifications about the pedestrians or the emergent vehicles used by the car navigation system. Also, there are some previous studies to identify the location only by the radio sensing such as [11].

Moreover, in the case of the traffic safety system for bicycles and pedestrians, it is necessary to consider the mobile devices such as the portable or light weight devices. Thus, it is supposed that smartphones are very effective devices because of the widely spread usages or various functions such as sensors. In fact, there have been some previous researches of the usages of smartphones for the traffic safety system.

First of all, the previous research [12] pointed out the difficulty in noticing electric vehicles approaching from the behind quietly, and it proposed a vehicle detection scheme using a smartphone carried by a pedestrian. The proposed methods introduce the approach of machine learning which is robust over the ambient noise, vehicle type, and vehicle speed, and the evaluations showed the proposed scheme can tell the vehicle speed and vehicle type. Although it is supposed that any other various sound factors from the electric motors will be needed for the additional researches, it is considered that the usages of smartphones are useful for the traffic safety from this research.

Secondly, some papers indicates the differences of characteristics from the smartphone's sensors for drivers or pedestrians. The paper [13] aimed to sense the abnormal car driver conditions such as impatience, fatigue, or overconfidence from the sensors on smartphones. Therefore, they investigated the abnormal driving determination method by comparing the current driving state using smartphones, and they observed the velocity, gyro, and GPS sensors on smartphones in order to detect rapid driving changes. Then, the abnormal car driver conditions are detected by the proposed methods based on the normal distribution, and the results are supposed to be effective. Also, the paper[14] proposed a pedestrian motion recognition method by geometrically transforming sensor data of a 9-axis sensors and by classifying motion features in device-independent coordinate system using Support Vector Machine with FFT or wavelet features. The results indicate the proposed method can distinguish from seven types of pedestrian motion; walk, right parallel movement, left parallel movement, right turn, left turn, run, and back movement by the sensors from smartphones. Moreover, the paper [15] discussed the simultaneous smartphone operations from the touch sensors and the camera.

These previous studies of the traffic safety system by smartphones suggested the possibility of the detections of the warning conditions by smartphones, and so this paper proposes the traffic accident prevention system with chronological variations of Wireless and Sensors on the Mobile phones in order to consider the both conditions between drivers and pedestrians or between bicycles and pedestrians.

3 Proposed Methods

The purposes of the proposed methods are to sense the dangerous smartphone operations during driving vehicles or bicycles, and to detect the rapid approaching objects even if the LTE or 3G networks are disconnected in the local areas. Thus, the system configurations of the proposed methods are shown as Fig 1. In the system, it is assumed that every driver, bicycle, and pedestrian carries the smartphone, and that the smartphone continuously observed carrier's motions and approaching carrier's movements. Then, if the system detects the abnormal operation in the driver or the bicycle rider, the smartphone is locked automatically. Also, if there is rapid approaching object to the pedestrian or the bicycle, the smartphone makes alert to the carriers.

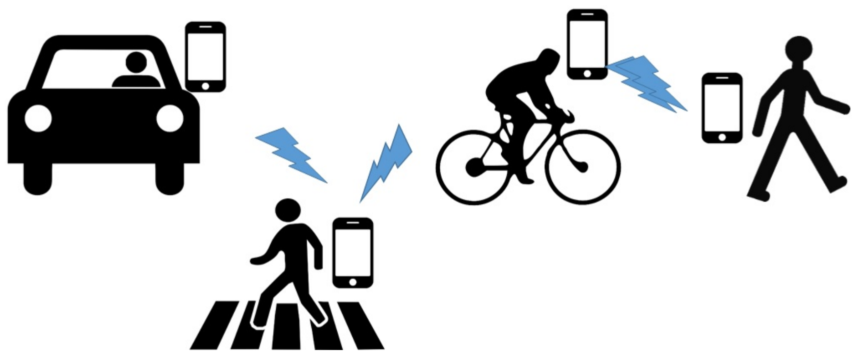

Figure 1: System architecture of the proposed system

Therefore, the proposed system takes account into two environmental categories from the smartphone. As shown in Table 1, one is the carrier's motion that is observed by the gyro, the accelerometer, the GPS sensor, and so on from the carrier's smartphone. Another is the other movements that is observed by the RSSI level and sound from the other smartphones. Then, to detect the rapid chronological changes, each observed value is held for the computational calculations based on the Markov Chain process.

Table 1: Two categories from the smartphone sensors.

Category	Sensors	Usages
Carrier	Gyro, Accelerometer, GPS, touch, light, proximity etc.	To sense abnormal operational behavior during driving or riding.
Others	RSSI, sound, Bluetooth	To detect other rapid approaching objects

The Markov chain process is a stochastic process that satisfies the Markov property. A stochastic process $X = \{X_n : n \geq 0\}$ on countable set S is a Markov Chain for any $i, j \in S$ and $n \geq 0$, A Markov Chain is defined as follows [16].

$$P\{X_{n+1} = j|X_0.X_1 \ldots X_n\} = P\{X_{n+1} = j|X_n\} \tag{1}$$

$$P\{X_{n+1} = j|X_{n.} = j\} = p_{ij} \tag{2}$$

The p_{ij} is the probability that the Markov Chain jumps from state i to state j. These transition probabilities satisfy $\Sigma_{j \in S} p_{ij} = 1$, $i \in S$, and the matric $P = p_{ij}$ is the transition matrix of the chain. Formula (1) called the Markov property that the next state X_{n+1} is conditionally independent of the past $X_0, X_1, \ldots X_{n-1}$ given the present state X_n. Also, Formula (2) is the transition probabilities do not depend on the time parameter n [16].

Then, each observed values are introduced for Formula (3) based on the Markov Chain model in order to detect the warning conditions.

$$X = \sum_{i=0}^{n} \alpha_i x_i + \delta \tag{3}$$

Here, X_i is the observed value when time sequence is t_i, α_i is the weight value that is satisfied with $\alpha_1 + \alpha_2 \ldots + \alpha_n = 1$, and δ is the adjustment values from the other sensors. Then, X_{th} which is the threshold value for the alert is previously set, and the alert process is confirmed if the $\Delta X \geq X_{th}$ occurs in the proposed methods.

For example, for the detection of others, the SSID, the radio band, the RSSI are periodically observed by the carrier's smartphone, and the each SSID's RSSI levels are used for the calculation of Formula (3). Then, if the calculated value is exceed to the threshold value, the alert process is confirmed for the carrier.

However, the authors are now planning additional algorithm based on deep learning theory in order to consider the decision making process by multiple observed values, and it is one of the future research subjects.

4 Prototype System

The authors are now implementing the prototype system for the evaluations of the proposed methods as shown in Fig. 2. In the prototype system, Nexus5X [17] is used for the smartphones, and the OS is set as Android ver7.0 [18]. Also, the Android Studio 2.1.2 [19] with Java 1.8.0 is used for the implementations, and the target API is set as API23 [20].

Fig 3 shows the state diagram of the proposed methods. At first, when the smartphones start the services in the assumed environments as Fig 1, every possible sensors including wireless network are activated. Seconds, these values are separated to two categories such as Table 1 in order to sense the dangerous carrier's operations during driving or riding bicycles and in order to detect the other dangerous approaching vehicles or bicycles. Then, each observed values are calculated by the proposed calculations, and the alerts are proceeded if there is a certain value of differences between the current values and the previous values.

In this paper, the WiFi detections for the rapid approaching objects in the proposed methods are implemented, the optimal weight values and the threshold value for detecting the dangerous conditions is discussed in the later. In the implements, at first, when the application is started, the smartphone scans the WiFi signals by using the wifiManager. The wifiManager [21] is one of the Android's instance, and it provides the scanning of the SSID, the frequency band, and the RSSI levels around the smartphone.

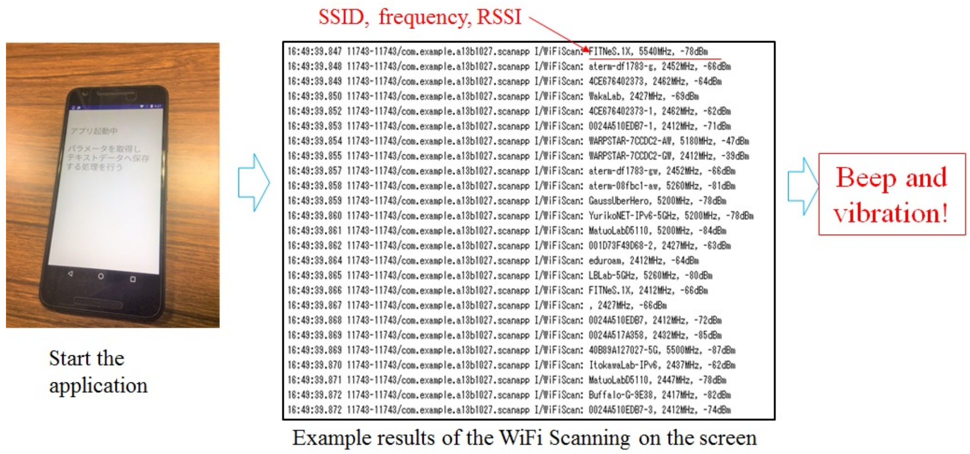

Figure 2: The prototype system

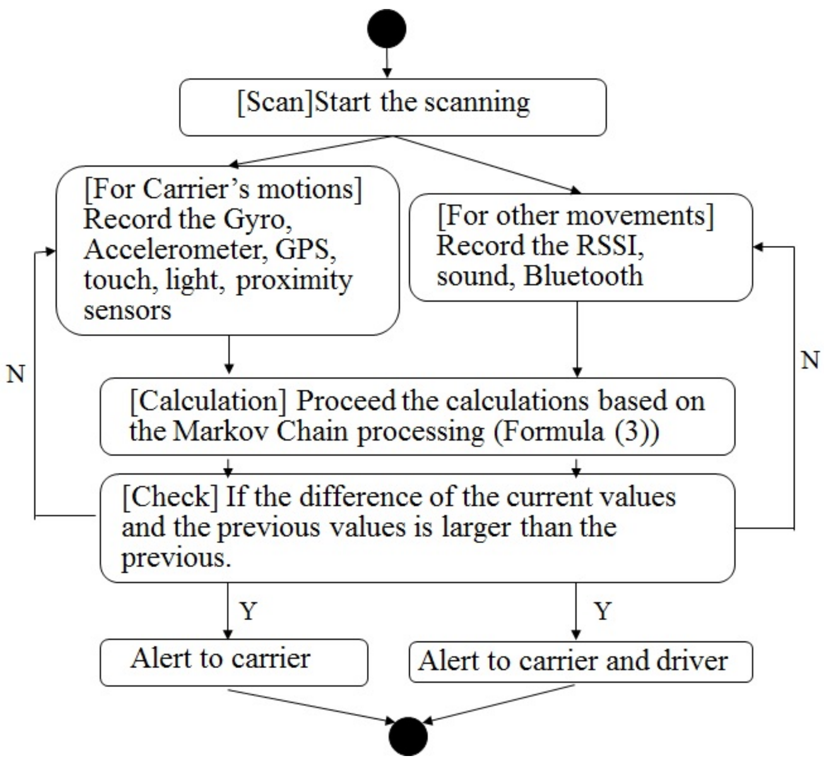

Figure 3: State diagrams of the prototype system

Secondly, these observed values are stored in the text file in the smartphone with the local time, and the detection of the dangerous conditions is held to detect the rapid chronological changes of the observed values. In the detection process, if the calculated value is more than the previously configured threshold value, the alert execution is proceed to the smartphone carrier. If not, the process get back to the WiFi scanning.

5 Experiments

In the experiments, the evaluations of WiFi detections in the prototype system was executed in this paper. Fig. 4 shows the network configurations of the experiments, and the experiments were held at the Fukuoka Institute of Technology, Japan. The outside open space in the campus is used for the setting of the experiments, and Node A was fixed at the 0m point, and the Node B was moved from the 50m point as shown in the figure. Then, the change of the RSSI levels are observed when the node B is moving toward node A with approximately 5 (pedestrian), 15 (bicycle), and 40 km/h (vehicle) in the experimental scenarios.

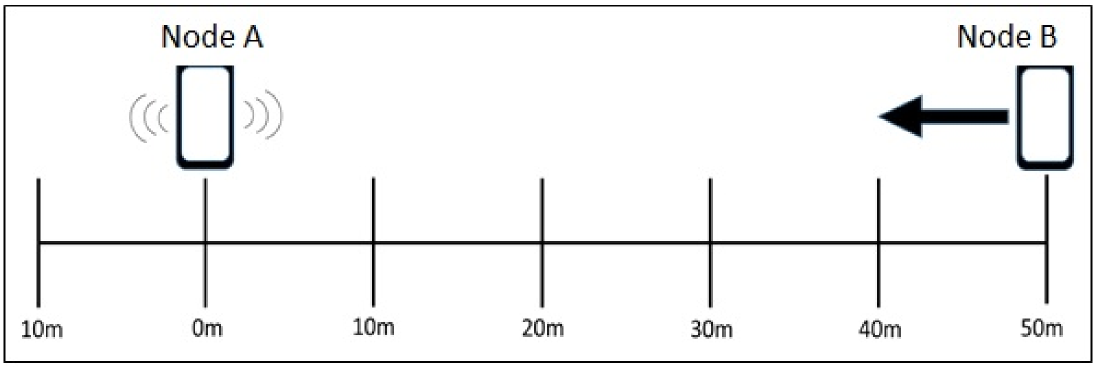

Figure 4: Network configurations of the experiments

At first, Fig. 5 shows the change of the RSSI levels through the seconds. As shown in the figure, there are the rapid decreasing values in every case of 5, 15, and 40km/h. However, since it is supposed that the radio transmission range is not enough by the IEEE802.11a/b/g/n/ac on the smartphone, there is no differences between these scenarios. Even though the speeds of every cases are different, the observed values are declined around 0 to 5 seconds in every speeds. Also, in case of 5 km/h, the accuracy of the WiFi detections seems to be problem because there are radio noises at 10 and 20 seconds. It is considered the radio noise such as multi-pass problems or the fading problems of the radio transmission, and this is the considerable subject of the adjustment values in the proposed methods in the future studies.

Next, the proposed calculations based on the Markov Chain process is proceeded by these observed values. In the experiments, three types of the weight values are introduced into the prototype system as Table 2.

Table 2: Three types of the weight values in the experiments

	Pattern1	Pattern2	Pattern3
α_1	0.7	0.6	0.5
α_2	0.2	0.3	0.3
α_2	0.1	0.1	0.2

Then, the calculated values based on Formula (3) are shown in Table 3, 4, and 5 by the each pattern of the weight values.

As the results, it is considered that the pattern 3 shows the most differences when other objects come closer to the carrier in comparison with pattern 1 and 2. The great differences are shown at the point between 10 and 15 seconds in the 5km/h, the point between 5 and 10 seconds in the 15km/h, and the

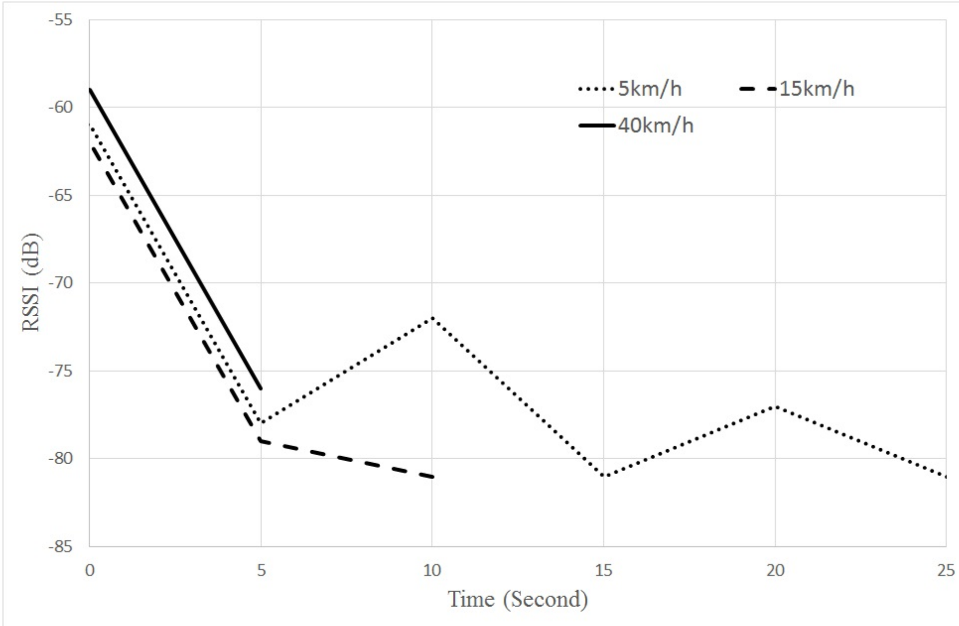

Figure 5: Results of the RSSI levels by the speeds

Table 3: The results of the proposed methods by the weight values of the pattern 1

Time(seconds)	5km/h	15km/h	40km/h
0	-80.2	-80.8	-71.9
5	-74.3	-77.7	-73.1
10	-77.1	-65.6	
15	-65.5		

point between 5 and 10 seconds in the 40km/h. Therefore, if the threshold value is set as from 5.0 to 7.5, the proposed methods are consider to detect the rapid approaching objects according to the experiments.

However, there are some subjects such as the effect of the radio noise in case of 5 km/h, it is necessary to consider the adjustment values for the future studies.

Table 4: The results of the proposed methods by the weight values of the pattern 2

Time(seconds)	5km/h	15km/h	40km/h
0	-79.8	-81.0	-80.5
5	-75.2	-80.8	-75.8
10	-76.5	-77.9	
15	-67.2		

Table 5: The results of the proposed methods by the weight values of the pattern 3

Time(seconds)	5km/h	15km/h	40km/h
0	-79.8	-70.9	-68.5
5	-75.7	-80.0	-78.5
10	-76.8	-81.0	
15	-68.3		

6 Conclusions and Future Studies

With the recent developments of Intelligent Transport System (ITS) such as the autonomous vehicles or vehicle-to-vehicle (V2V) communication system, it is expected that the traffic accidents are decreased in the near future. However, it is necessary to concern the traffic accidents including vehicles or pedestrians recently, and it is supposed that the usages of the mobile devices such as smartphones are very effective methods. Therefore, this paper proposes the mobile traffic accident prevention system based on the chronological changes of wireless and sensors on the mobile phones.

In the proposed methods, the mobile devices continuously observe the wireless signals and multiple sensors on the mobile devices, and the observed values are calculated by the Markov Chain algorithm. Then, the prototype of the system is reported, and the experiments are discussed for the effectiveness of the proposed methods and the future studies.

Although the experiments of the WiFi detections suggested the proposed methods are effective for the proposed mobile traffic accident prevention system, but, there are also some problems that it is necessary to take into account for the future studies. Therefore, the future studies includes the additional implementations for the decision process that is based on the Markov Chain model, and the additional field experiments for the evaluations of the proposed methods. Also, the implementations of the other sensors except WiFi detections are now working for the future studies.

Acknowledgments

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References

[1] Asahi News Paper, August 25, 2016, http://www.asahi.com/shimen/20160825/index_tokyo_list.html, [Online; Accessed on September 1, 2017].

[2] Tokyo News Paper, October 27, 2016, http://www.tokyo-np.co.jp/, [Online; Accessed on September 1, 2017].

[3] "The road traffic regulation in tokyo," http://www.reiki.metro.tokyo.jp/, [Online; Accessed on September 1, 2017].

[4] S. Takeuchi, N. Uchida, and Y. Shibata, "Proposal of traffic accident prevention system with chronological variations of wireless signals and sensors on mobile node," in *Proc. of the 11th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS'17), Torino, Italy*, ser. Advances in Intelligent Systems and Compuitng, vol. 612. Springer, Cham, July 2017, pp. 68–72.

[5] S. Kato, N. Minobe, and S. Tsugawa, "Experimental report of inter-vehicle communications systems : A comparative and consideration of 5.8ghz dsrc, wireless lan, cellular phone," IEICE Technical Report, Tech. Rep. 242, 2012.

[6] T. Aizawa, H. Shigeno, T. Yashiro, and Y. Matsushita, "A vehicle grouping method using w - cdma for road to vehicle and vehicle to vehicle communication," IEICE Technical Report, Tech. Rep. 83, 2000.

[7] Y. Adachi, T. Umezu, H. Yamaguchi, and T. Higashino, "V2x content delivery scheduling for efficient vehicle information sharing," IEICE Technical Report, Tech. Rep. 16, 2014.

[8] I. Sakamoto, H. Hozuku, T. Kojima, G. Natsynyra, T. Takeuchi, T. Hasegawa, and Y. Tanaka, "Fundamental study for inter-vehicle communication using smartphone (in japanese)," https://www.ntsel.go.jp/forum/forum2013.html, [Online; Accessed on September 1, 2017].

[9] H. Yoshida, M. Nakano, Y. Watanabe, and M. Sugyama, "A study of accident prevention both of bicycle and pedestrian by approaching detection based on mobile gps," IPSJ SIG Technical Report, Tech. Rep. 10, 2015.

[10] TOYOTA, "Toyota cars web site toyota's latest technology," http://toyota.jp/technology/safety/itsconnect/, [Online; Accessed on September 1, 2017].

[11] C. J. Zinsmeyer and T. Korkmaz, "A comparative review of connectivity-based wireless sensor localization techniques," *Journal of Internet Services and Information Security (JISIS)*, vol. 2, no. 1/2, pp. 59–72, February 2012.

[12] M. Takagi, K. Fujimoto, Y. Kawahara, and T. Asami, "Detecting hybrid and electric vehicles using a smartphone," in *Proc. of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp'14), Seattle, Washington, USA*. ACM, September 2014, pp. 1–8.

[13] T. Wada, K. Fukumoto, and H. Okada, "Fundamental study on abnormal driving determination method using android smart phone," IEICE Technical Report, Tech. Rep. 5, 2014.

[14] H. Togashi, T. Ikeda, and K. Kurumatani, "Orientation-independent method for simultaneous recognition of pedestrian motion type and motion direction using 9-axis sensor on smartphones," IEICE Technical Report, Tech. Rep. 356, 2014.

[15] Y. Okamoto, K. Sumi, K. Makita, T. Nakano, A. Watanabe, and M. Yamada, "An examination of a detection method for simultaneous smartphone operation," pp. 1483–1486, July 2013.

[16] R. Serfozo, *Basics of Applied Stochastic Processes*. Springer Science & Business Media, 2012.

[17] "Nexus 5x google," https://www.google.com/nexus/5x/, [Online; Accessed on September 1, 2017].

[18] "Google android," https://www.android.com/intl/en_us/, [Online; Accessed on September 1, 2017].

[19] "Android studio," https://developer.android.com/studio/index.html, [Online; Accessed on September 1, 2017].

[20] "Android 6.0 apis android developers," https://developer.android.com/about/versions/marshmallow/android-6.0.html, [Online; Accessed on September 1, 2017].

[21] "Android developers wifimanager," https://developer.android.com/reference/android/net/wifi/WifiManager.html, [Online; Accessed on September 1, 2017].

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