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Develop algorithms to determine the status of car drivers using built-in accelerometer and GBDT

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ABSTRACT

In this paper, we introduce a mobile application called CarSafe, in which data from the acceleration sensor integrated on smartphones is exploited to come up with an efficient classification algorithm. Two statuses, "Driving" or "Not driving," are monitored in the real-time manner. It enables automatic actions to help the driver safer. Also, from these data, our software can detect the crash situation. The software will then automatically send messages with the user's location to their emergency departments for timely assistance. The application will also issue the same alert if it detects a driver of a vehicle driving too long. The algorithm's quality is assessed through an average accuracy of 96.5%, which is better than the previous work (i.e., 93%).

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1. INTRODUCTION

According to statistics, on an average year, Vietnam has about 8,000 deaths, 15,000 injured due to traffic crashes. Thus, economic losses are estimated at 5 to 12 billion US $. There are many reasons for crashes, such as using the phone to watch movies, listen to music or text, call while driving [1], [2]. Those behaviors are very potential to cause crashes.

CarPlay and Google Android Auto are two intelligent systems of Apple and Android installed on automobiles to use the interface's phone features on the screen by car [3]-[5]. These technologies' ultimate purpose is to help users use the necessary functions on the phone in the most convenient way, limiting manipulation, focusing on the journey. The benefits that Android Auto and Apple CarPlay bring are undeniable. However, these two systems are mostly integrated into modern vehicles. There have also been studies focusing on safe driving in the past. These studies are mainly focused on smartphone services, built-in inertial sensors in the car or on the phone [6], [7]. We want to fulfill other applications' insufficiencies; thus, this paper proposes building software installed on all smartphones running Android operating systems to support automobile drivers. Our contributions can be summarized as follows:

The software automatically recognizes the car's in-car status, automatically turns on Bluetooth to support hands-free calling, and turns off Bluetooth to save the battery if it detects the user is no longer riding again. Some essential features have been added, such as automatically read aloud short message service (SMS messages from Gmail or Messenger. Detect the crash and automatically make emergency contact with the relative person with the user's address. It alerts the driver to erratic driving and drives for too long. Driving for a long time can cause fatigue and accidents.

The paper has four sections. After the introduction, we will present the software system's design model using the machine learning algorithm and the accelerometer sensor built into the phone and presents an algorithm to identify the driver's status in section 2. The results and evaluation of the effectiveness of the proposed system are analyzed in section 3. Finally, the conclusions are presented in section 4.

2. MODEL OF THE SOFTWARE DESIGN SYSTEM

2.1. System design

The software system that identifies cars' driving state using machine learning algorithms and a built-in accelerometer is designed with the functional principle diagram, as shown in Figure 1. If the "Driving" status is identified using a machine learning algorithm, the phone will automatically activate Bluetooth to help the driver make the hands-free conversation mode. It automatically receives messages from SMS, Gmail, or Messenger. Suppose a crash is expected to occur with the driver. In that case, the application will confirm with the user by vibrating vigorously and present a voicemail asking if a crash has occurred or not. It avoids issues of false alerts. In 10 seconds, if there is no response by clicking confirmation on the dialog box from the user, the software will default to a crash and automatically turn on global positioning system (GPS) to get information about the driver's current location. It then automatically send notification messages with GPS coordinates and map links to their emergency departments to receive timely help.

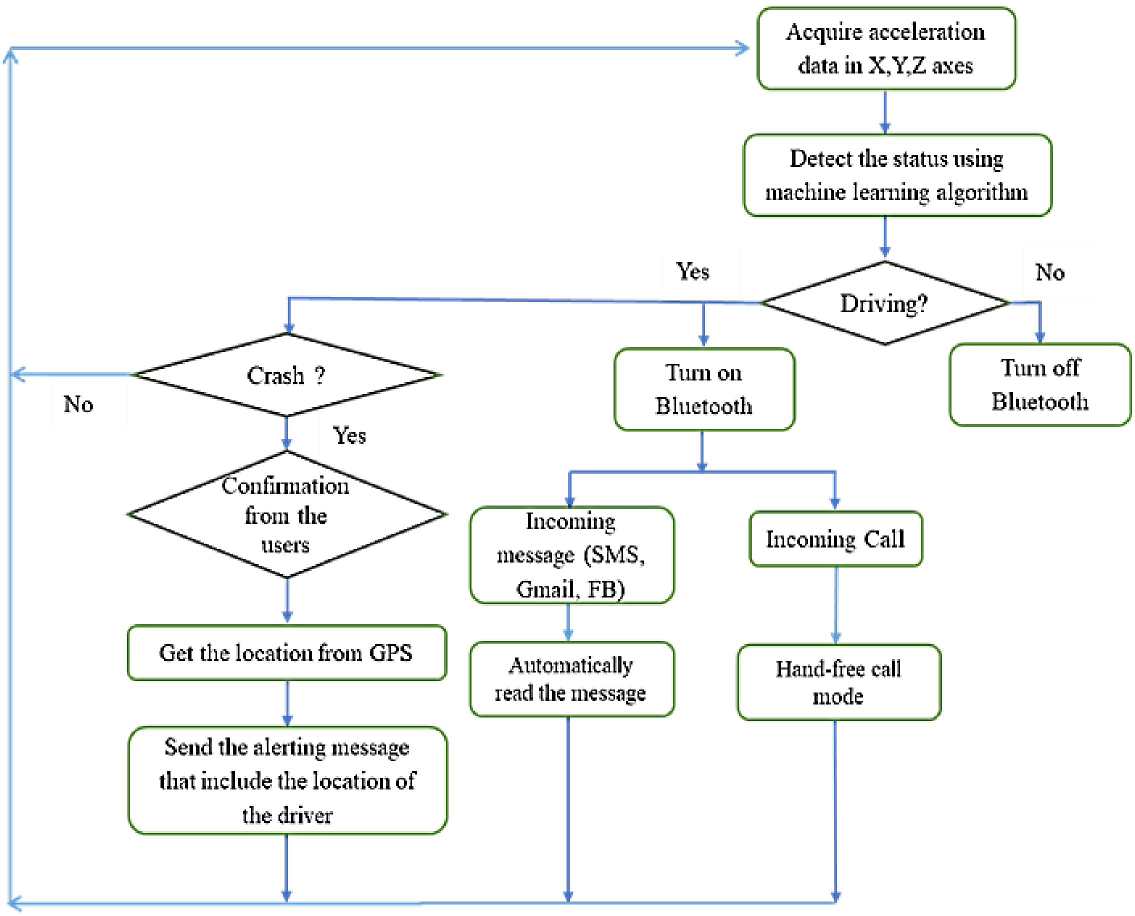

Figure 1. Diagram of the operating principle of the software system

The program can detect the "Driving" status using the acceleration data from the built-in accelerometer. However, we did not provide the raw acceleration data for the machine-learning model. We extract a feature set from the acceleration data. The entire process of determining the status of the driver is shown in Figure 2.

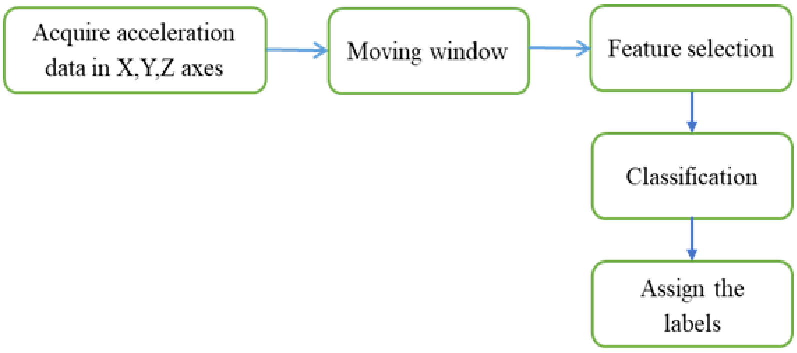

Figure 2. The process of classification of driver status

2.2. Collect data from the accelerometer

The sensor provides 50 samples of the acceleration data every second along the three axes [6]. After conducting data collection from the accelerometer sensor [7], we used a 14-second sliding window to extract the designed features. The monitor data is then labeled in a data set. Table 1 shows an example of observations. The dataset includes 2560 direct observations distributed to the state shown in Table 2.

Table 1. An observation sample along three axes X, Y, and Z

	Driving	
Acceleration in X (g)	Acceleration in Y (g)	Acceleration in Z (g)
- 0.0867	1.2008	9.9403
0.1540	0.7493	9.9128
0.6307	0.1791	9.8924
0.3528	- 0.3694	10.7692
- 0.1083	- 0.2652	10.6853
0.3768	0.2378	9.1378

Table 2. The number of samples observed for each state

Status	Number of samples observed
On Vehicle	581
On Bicycle	308
On Foot	669
Still	899
Tilting	103
Total	2560

2.3. Feature selection

This paper proposes and conducts a feature selection because the classifier can provide better classification results [8]. t-distributed stochastic neighbor embedding (t-SNE) is a non-linear technique to map multidimensional data to lower dimensional space [9]. This study uses the t–SNE technique to map each data point (X, Y, Z) in 3-dimensional space to 2-dimensional space for visualization, easy for data observation. Figure 3 shows the distribution of the training data set without natural selection in 2-dimensional space using the t-SNE technique. The data set does not seem to be stratified when states overlap and overlap. Thus, it is clear that the pretreatment process's influence and natural selection affect the model's classification performance [10], [11].

Figure 4 shows a better result so far in terms of the 5-state classification when each state has been clearly separated, leaving only a small amount of data mixed into other classes. Thus, the characteristic selection was conducted and brought outstanding results to classify five states when selecting four characteristics, including average, median, RMS, and range. Table 3 presents a summary of the chosen features from where $X$is the set of acceleration samples, N is the number of samples, and x_i the value of the i[th] sample in the set X.

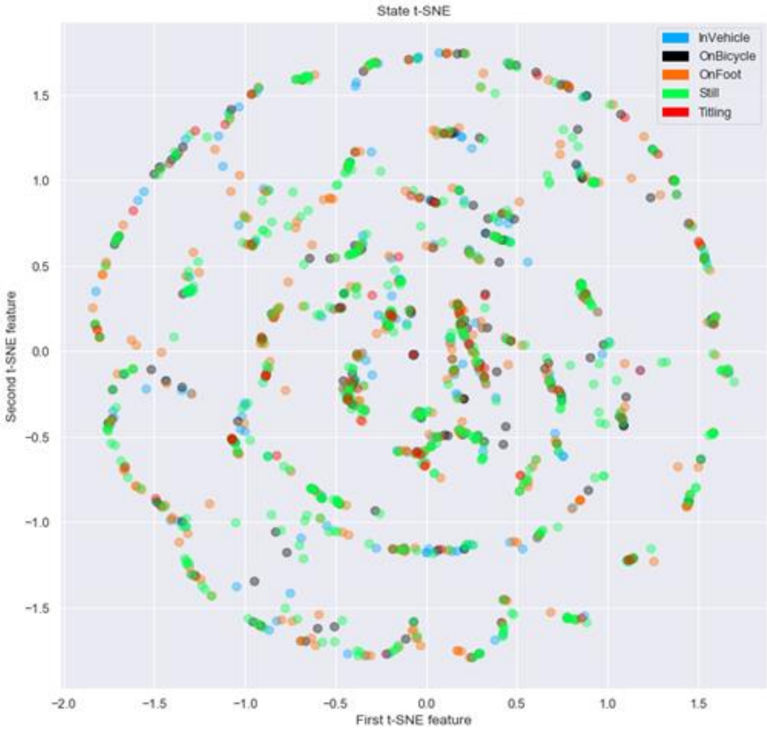

Figure 3. Performing t-SNE collective training data before choosing characteristic

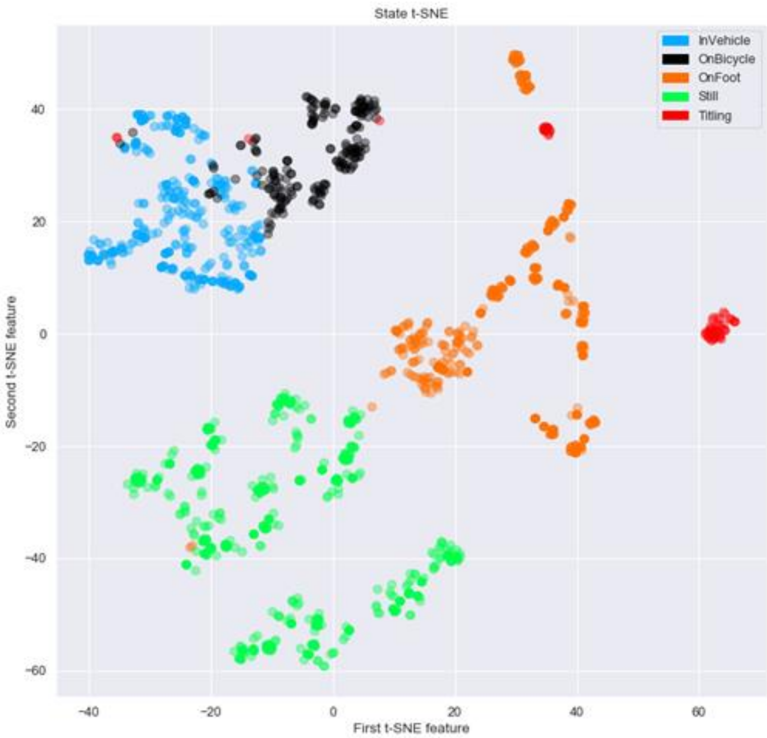

Figure 4. Performing t-SNE using four chosen features

Table 3. The feature formulas

Features	Formula
Mean	Mean $(X) = \frac{1}{N}\sum_{i=1}^{N} x_i$
Median	Median $(X) = \frac{1}{2}\left(x_{\left[\frac{N}{2}\right]} + x_{\left[\frac{N}{2}+1\right]}\right)$
RMS	$RMS_X = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2}$
Range	Range $(X) = [min_{i=1}^{N}\{x_i\}, max_{i=1}^{N}\{x_i\}]$

2.4. State classification algorithm

Referring to the activity classification service Google activity classification [12], we collect five states' data and design a machine learning model to accurately classify those five states from the original dataset, including on vehicle, on bicycle, on foot, still, tilting. The activities are described in detail in Table 4. Four states (on bicycle, on foot, still, tilting) are grouped to a final state, "No driving." From the input featured data, 60% of the data is for training, and the remaining is for testing. These data sets go through the feature selection step to find the best features for the data set. In this study, we used the gradient boosting decision tree (GBDT) method [13]. GBDT can be used in the classification problem due to its strong generalization ability [14], [15].

Table 4. States description

Status based on [12]	Descriptions based on [12]	Status in our study
On vehicle	The equipment is in the vehicle (car, bus, taxi, truck). The user can be a driver or a passenger.	Driving
On bicycle	The user is on a bicycle.	No driving
On foot	The user is lying, running or walking.	
Still	The device is still in the previous state (stay still, do not move)	
Tilting	The angle of the device relative to gravity is much changed. This state usually occurs when picking up the device from the bottom up (from the table up, from the ground up) or in the user's pocket while learning to sit up.	

3. RESULTS AND DISCUSSION

To clarify the proposed software solution's effectiveness in determining the driver's state using data from the accelerometer sensor built into smartphones and the decision tree (DT) machine learning algorithm, we conducted a review. The overall performance of the DT model reaches 95.1% for all classified states. Tables 5 and 6 list the performance parameters for each state. In particular, the states on vehicle, still are classified accurately to a high level. Overall accuracy (accuracy) is suitable for all classes (greater than 90%). The best precision has been achieved with on vehicle, still, and on foot; the remaining states reach the right level with a slightly lower value. Sensitivity is very high, meaning there are not many negative cases that are misclassified as positive. The demo clip of our application is found at the link https://youtu.be/ZbbJ1nmHhvE. It can be seen that our application software can contribute to improving transportation safety [16]-[25].

Table 5. The confusion matrix

Observed States	Predicted States					Total
	On Vehicle	On Bicycle	On Foot	Still	Tilting	
On vehicle	**226**	1	0	0	0	227
On bicycle	5	**115**	36	0	0	156
On foot	0	0	**230**	2	0	232
Still	0	0	0	**356**	0	356
Tilting	0	6	0	0	**40**	46
Total	231	122	266	358	40	1017

Table 6. Algorithm performance evaluation parameters for each state

Status	Algorithm performance evaluation parameters		
	Accuracy	Precision	Recall
On vehicle	99.4%	99.5%	97.8%
On bicycle	95.3%	73.7%	94.3%
On foot	96.2%	99.1%	86.5%
Still	99.8%	100%	99.4%
Tilting	99.4%	87%	100%

3.1. Evaluate the level of energy consumption

Smartphones from Samsung, Huawei, HTC, LG, or Sony all have to face device battery life problems. Android smartphone batteries rarely exceed 36 hours of use. The recent commercial campaigns of Samsung Galaxy show that Samsung has operated in super energy saving mode. When you activate this mode, your phone will change the color screen to a black and white screen. It also limits the number of apps that you can use. In our study, we worked with the phones in Table 7 to evaluate the energy consumption and proposed some solutions as follows:

- Although the information is also extracted from GPS, but only automatically activates this device when a crash occurs; In other normal operations, GPS does not need to be turned on.
- The sensor's sampling rate in the phone can be reduced (while avoiding unnecessary, constant state transitions).
- Users can start and stop using the software manually to save energy.

Table 7. Algorithm performance evaluation parameters for each state

No.	Model	Consumption when using the software (with GPS), calculated by the decreasing percentage per day (%)	Consumption when using the software (not using GPS), calculated by the decreasing rate per day (%)
1	Oppo A37	35.6	25.0
2	Oppo A71	34.7	23.1
3	Oppo A83	32.5	22.4
4	Oppo F5	30.3	21.6
5	Samsung J7	35.3	25.5
6	Samsung J7 Plus	34.5	23.8
7	Samsung A8	32.6	22.7
8	Samsung Galaxy A9 Pro	30.8	21.9
9	Samsung S6	27.3	20.1
10	Samsung S7	26.2	20.3
11	Samsung Galaxy S8	25.4	20.2
12	Xiaomi Note 5A	35.1	25.4
13	Xiaomi 4X	34.0	23.6
14	Xiaomi Note 4	32.3	22.5
15	Xiaomi Mi A1	30.6	21.7
16	Sony Xperia L2	35.7	25.6
17	Sony Xperia M5	34.8	23.8
18	Sony Xperia XA1	32.1	22.9
19	Sony Xperia XZ1	30.2	21.7
20	Lenovo K6 Power	32.3	22.4
21	Lenovo K6 Note	30.5	21.3

4. CONCLUSION

This paper built an Android application to assist the driver of safe cars. We focused on studying the specific features based on the acceleration data. We used the GDBT algorithm to classify data into five states: on bicycle, on foot, still, on vehicle and tilting. Our machine learning model in the proposal makes the overall model accuracy reach 96.5%. This result outperformed the overall accuracy of 93% in the previous work.

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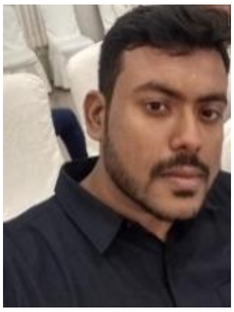

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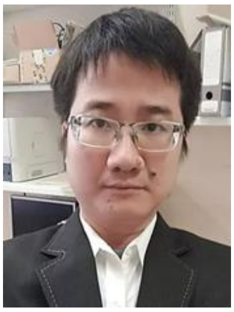

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