Driving Safety Application Using Wearable Device and Mobile Technology

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DRIVING SAFETY APPLICATION USING WEARABLE DEVICE AND MOBILE TECHNOLOGY

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Abstract

This research is conducted to help motorbike riders in avoiding accidents caused by drowsiness. The wearable device technology used was smartband and accelerometer from Android smartphone. It was used to obtain heart rate data and detect drowsiness experienced by motorbike riders. An accelerometer was used to detect if an accident occurs and send the information to the driver's family. The method in this research was quantitative research and development. The results obtained showed that detecting drowsiness is equal to 80% and the accident detection test gets an accuracy of 100%. The accuracy of drowsiness detection during the day is 75% and testing that carried out at night has an accuracy rate of 90%. Functional suitability test results obtained a value of 100%, compatibility aspects have 100%, usability aspects of 84.7%, and performance aspects in terms of response time are in the range of satisfaction equal to 3.88 seconds. The tests conducted using Likert scale showed that the application is feasible to use, and the driving safety application has reached its desired purpose. This research impacts on driving safety that must prioritize safety both for self and for others.

Keywords: Accelerometer, Drowsiness, Motorbike driver, Safety ride, Smartband,.

1. Introduction

Based on data released by the NTSC Indonesia from 2010 to 2016, 41 accident investigations caused as many as 443 fatalities. One of the causes of accidents comes from driver error. There were 69.7% of motor vehicle accidents caused by sleepy motorists [1]. Drowsiness is a condition where someone feels like sleeping. Drowsiness can happen at the inappropriate time, for example working, studying, or driving. Sleepiness is usually characterized by fatigue, loss of consciousness, falling asleep, interference with activity [2], and forgetting [3]. Besides of hurting oneself, it can also harm other motorbike riders.

Drowsiness can trigger various problems, such as disturbing driving performance [4], productivity, affecting one's emotions, disturbing social interactions, and the most fatal is accidents both on the road and in the work environment [5]. Accidents can occur not only because of human factors but also road or vehicle factors. Accident can be handled well if the driver is still conscious and asks for help or a family member knows if there is an accident just occurred. There are cases of late accident handling because the family do not know [6]. An accelerometer sensor can detect the tilt or change the position of an object so that family can know information about accidents [7].

Several studies have been conducted related to this research such as wearable device technology use for drowsiness detection [8], text messaging use to control smartphones remotely [9], accelerometer data use to identify idling times of a vehicle [10] and assess road quality [11]. In this research, to detect drowsiness is the Mi Band 3 smartband because it can track the user's activities such as heart rate [12], sleep quality [13], and activity trackers [14].

In contrast to Aloul's research which uses smartphones to detect car accidents, this research uses smartphones and wearable devices to detect motorbike rider accidents [15]. A smartband retrieved the motorbike driver's heart rate data and sent it to Android smartphone to calculate the average heart rate. If it is categorized as sleepy, the smartband will vibrate and the smartphone will sound an alarm. When an accident driving is occurred, the accelerometer sensor on Android smartphone will detect the location and time data then send it to the family. This research aims to build a driving safety application and uses a software development life cycle method for the system development process.

2. Method

This research consisted of several stages. The initial stage is to carry out case analysis to obtain accident-related data, analyse sleepiness, and accidents up to the implementation stage, and system testing. Figure 1 shows the stages flow carried out in this research.

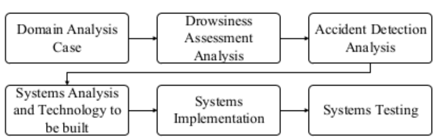


Fig. 1. Stage of research method.

2.1. Domain Analysis Case

At this stage, an analysis of cases is carried out in the form of an analysis of common problems when driving accidents. There is up to 69.7% of motor vehicle accidents caused by rider drowsiness. Every day many riders are passing by on the highway. Based on data from BPS Indonesia (Central Bureau of Statistics) recorded that until 2017, there were 138,556,699 motor vehicles units in Indonesia. This number is increasing every time and it can also cause higher accident rates.

Drowsiness while riding can occur due to several factors such as fatigue or the urge to sleep at night [16], long travel, or less fit body condition. Drowsy while also riding can-do harm to other riders. Drowsiness is a condition in which a person feels like to sleep. It can happen at the most opportune times, such as at work while studying or while riding. Thus, the results of the domain analysis case stage in this study are that several reasons can cause driving accidents, one of which is sleepy.

2.2. Drowsiness assessment analysis

At this stage, an analysis of the heartbeat data obtained from the smartband was calculated based on previous studies to determine the driver's condition. It is because drowsiness usually occurs because of lack of sleep. Everyone has different sleep needs, depending on age and daily activities. Ideally, adults need 7-9 hours of sleep per day, while children and teenagers need 9 hours, toddlers need 10-12 hours, and the new-born takes 16-18 hours. The following workflow of drowsiness assessment in this research is shown in Fig. 2.

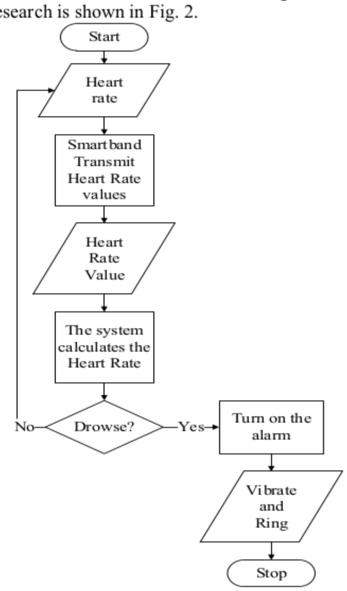


Fig. 2. Drowsiness assessment workflow.

Drowsiness detection application was made using smartband. It can be used on the left or right wrist to detect the heart rate. Mi Band 3 uses green LED light paired with a light-sensitive photodiode to detect the heart rate flowing through the wrist. When the heart beats, the smartband will reflect light and its reflections is readable by a photodiode. If it does not reflect light, this means that the heart rate is high. Through the observation, the sensor analyses the data and calculates the heart rate. Through blinking LED lights hundreds of times per second, Mi Band 3 can calculate the heartbeat frequency.

The heart rate is the number of heartbeats per unit of time, usually expressed in beats per minute (bpm) [17]. The normal heart rate of adults is 60-100 bpm with the heart rate maximum is 220 - age [18]. Table 1 below shows a normal heartbeat.

Table 1. Normal heart rate.

Age	Normal Heart Rate
1-2 years	80-130
2-6 years	70-120
6-10 years	70-110
Ten years and over	60-100

The time body relaxes either at rest, drowsiness, sleep, and heart rate is relatively slower than doing the activity. In general, the decline ranges from 10-20% of the current state of operation. This value has been validated by an expert Doctor.

2.3. Accident detection analysis

At this stage, an analysis of the smartphone slope data was calculated based on the data from previous studies. It is done to determine the position of the motor falls is to the left or right. A smartphone today generally already has an accelerometer sensor for various needs, such as changing the display from portrait to landscape by tilting the body of the phone. It happens because of a change to the coordinates x, y, and z smartphone. The x-axis is the form of a horizontal line, a vertical line forming the y-axis, and a z-axis pointing to the front and rear of the display device. Accelerometer values is shown in Table 2.

Table 2. Accelerometer axis value.

Position	X	Y	Z
Vertical	0	1	0
Vertical reversed	0	-1	0
Left landscape	1	0	0
Right landscape	-1	0	0
Flat	0	0	1
Flat reversed	0	0	-1

The calculation of the value of the accelerometer is focused on the x-axis. This is because the amount of x to determine the slope of smartphone, which is placed on the speedometers to find out the overall effect accelerometer and to detect an accident. The following workflow drowsiness ratings is shown in Fig. 3.

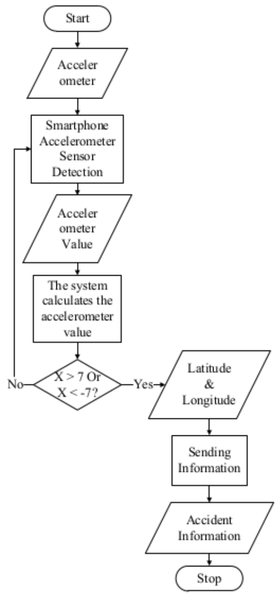


Fig. 3. Accident detection workflow.

2.4. Tools and technology

The technologies used in this research are as follows:

a. Smartband
Smartband was used to get the heart rate that detects drowsiness. Smartband is a device or application for monitoring and keeping track of fitness-related metrics such as walking or running distance, calorie consumption, heart rate, and sleep quality.

b. Accelerometer
This technology was used to get slope data of the smartphone and identify an accident. In this research, the accelerometer was used as a detector of the wave of the vehicle due to holes or damaged roads. It can change the display from portrait to landscape by tilting the smartphone to read three axes from different directions [19].

c. Google Maps API
It is used to get the latitude and longitude values in detecting the location of current accident [20].

d. SMS Gateway
This technology is used to provide and send information to a registered destination phone number when accident occurs [21].

2.5. System implementation

At the application development, along with the implementation of technology, it has been analysed previously. At this stage, the start of implementation drowsiness assessment, implementation of crash detection, smart band linking implementation, and the implementation of the SMS Gateway was done.

2.6. System testing

The results of this stage are testing process analysis technique based on functional suitability, compatibility, usability, and efficiency. The functional suitability test was assessed by the Guttman scale. After getting the test results in the form of points, it was then analysed using criteria in the document quality for Android applications as shown in Table 3.

Table 3. Functional Quality Standards Suitability.

Rankings	Warning	Critical
No error	0 points	0 points
An easy mistake	1 point	-
Difficult errors	2 points	-
Fatal error	4 points	-
The test fails	-	5 points

Compatibility analysis was conducted by operationally test series with the commencement of the installation of applications on different versions of operating systems and various specifications of smartphones based on the Android platform [22]. The next stage of calculating the percentage score test results is to determine the quality level of compatibility aspects, namely:

$$\text{Percentage of Eligibility} = \frac{\text{Score obtained}}{\text{Maximum Score}} \text{ x } 100\,\% \qquad (1)$$

The usability aspect test was used Likert scale. The instrument's use questionnaire consisted of 30 questions for users to show the attitude towards ease of use of the application [23]. After finding the results of the calculations score, then a comparison with the criteria in Table 4 was made [24].

Table 4. Criteria interpretation score.

Percentage (%)	Interpretation
0% - 20%	Very unfit
21% - 40%	Less worthy
41% - 60%	fairly decent
61% - 80%	worthy
81% - 100%	very decent

Quality analysis of the efficiency performance was done by calculating the average response time of each activity. It was executed using program function trace view [25]. Tests on the performance aspect performed at least five times the amount calculated average response time when an application retrieves data from the server and then shown into the system [26]. The results are then compared in Table 5 user satisfaction with the response time [27].

Table 5. User satisfaction predicate.

Response Time (seconds)	Predicate
<3	Very satisfied
3-9	Satisfied
9-12	Quite happy
> 12	Not satisfied

3. Results and Discussion

These stages include results from testing assessment and discuss the results obtained for the implementation of further research.

3.1. Drowsiness assessment

Calculation of heart rate obtained are sent to the smartphone using Bluetooth 4.0 connection from Mi Band 3. The heartbeat data received by smart band are reprocessed to get the average heart rate. Here is the value of heart rate in normal conditions of 5 samples at the age of 21-23. The calculation of the average calculation of each sample are obtained while relaxing, during activity, sport, or at rest which is shown in Table 6.

Table 6. Calculation of heart rate average (BPM).

Sample	Age	Relaxing	Activity	Sport	Rest
1st sample	23	65	85	105	56
2nd sample	21	72	91	112	64
3rd sample	22	64	82	102	60
4th sample	22	62	80	98	54
5th sample	22	68	88	101	58

A summary from Table 6 is the average heart rate when relaxing = 66 BPM, during activity = 85 BPM, sport = 104 BPM, and rest = 58 BPM. Based on Table 6, it can be concluded that if the average heart rate of each person is different. Moreover, the theory from an expert doctor claim that if a person experiences drowsiness, the heart rate will decrease by approximately 10 to 20%. Calculation of the average heart rate was done in 15 seconds. The example of drowsiness assessment was a rider aged 22 years with a fit condition and has a regular heart rate of 80 BPM. From the theory when a person experiences drowsiness heart rate decreases by 10-20% from the current normal circumstances, the following formula determines the heart rate when a person is drowsy.

$$H_{beat} = N_{beat} - \frac{20}{100} \text{ x } N_{beat} \quad (2)$$

If $N_{beat} = 80$, then :
$H_{beat} = 80 - 16$
$H_{beat} = 64$ BPM

If the rider's heart rate is less than 64 BPM or 64 BPM, it is considered drowsy.

3.2. Detection of accident assessment

In this study, the smartphone was attached to the top speedometer. Table 7 shows the standard minimum values and maximum values accelerometer in a normal condition.

Table 7. Testing standard value accelerometer.

Axis	Minimum (m/s²)	Maximum (m/s²)
X	-0.13	0.16
Y	3.12	3.23
Z	8.70	9.65

Table 8 shows the minimum and maximum value from the accelerometer when receiving shocks while riding. The shocks that occurred were small to moderate shocks.

Table 8. Testing shock value accelerometer while riding.

Axis	Minimum (m/s²)	Maximum (m/s²)
X	-2.91	3.48
Y	2.61	5.44
Z	4.69	12.68

The occurrence of sudden braking also causes shocks. Table 9 shows the minimum and maximum values from the accelerometer when receiving shocks and a sudden brake is applied.

Table 9. Testing value accelerometer when brakes sudden shocks.

Axis	Minimum (m/s²)	Maximum (m/s²)
X	-3.52	3.86
Y	0.38	8.02
Z	0.28	20.20

Table 10 shows the minimum and maximum values from the accelerometer when receiving a shock during an accident occurs with the motorbike position falls to the right. While riding, it will declare in a motorbike accident in which position fell to the right.

Table 10. Accelerometer shock value current testing accident occurs.

Axis	Minimum (m/s²)	Maximum (m/s²)
X	-23.06	9.87
Y	-4.38	10.67
Z	-17.20	24.74

For the example assessment of the accident, a 22-year-old motorbike driver suffered an accident that caused the motor to fall to the right and give the accelerometer value on the x-axis of -7.56 m/s. After several experiments conducted in this research, it can ensure that the motorbike is said to have fallen when the value of the axis x>7 m / s or x<-7 m/s. To determine an accident occurred used a logical formula which show as follows:

$$A_{BL} = X_{axis} > 7 \vee X_{axis} < -7$$

If X_{axis} = -7.56, then:
A_{BL} = -7,56>7 ∨ -7,56 <-7
A_{BL} = false ∨ true
A_{BL} = true
When A_{BL} is true, then it will be detected as an accident.

3.3. System architecture

The system architecture in this research is shown in Fig. 4. The smartband is used to detect the motorbike driver heartbeat. When the system detects drowsiness, it will sound an alarm and vibrate to riders. If an accident occurs, the system will detect it, take the scene, and send the location information via SMS to the family of the victim or the destination number that has been registered in the application.

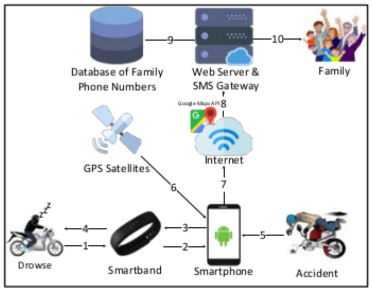


Fig. 4. System architecture.

The system procedure describes the activity process from the side of the driver, the system, and the family. A description of a system procedure in this research is shown in Fig. 5.

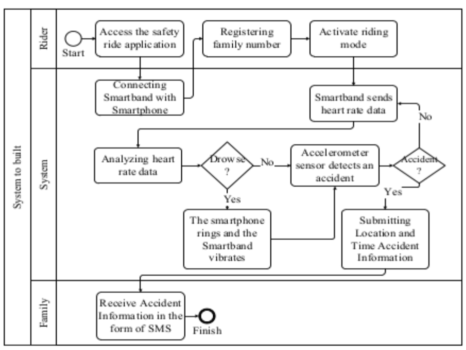
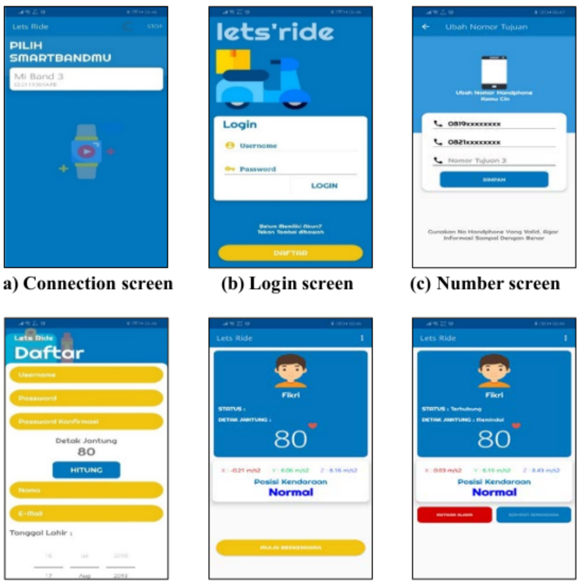


Fig. 5. System procedure.

3.4. System Implementation

This application requires installation on Android smartphone with minimum version of 5.1 (Lolipop). Figure 6 shows the system implementation result. The interface for the coupling smartband and smartphone shown in Fig. 6(a). On this page, there is a list of devices that can be connected. The login screen is shown in Fig. 6(b), which this page use to log in. Figure 6(c) shows the destination phone number to send information about the location and time if an accident occurred. Figure 6(d) is the registration menu. The main screen shows in Fig. 6(e). This page displays the heart rate and accelerometer value equal to Fig. 6(f). This figure shows the riders condition while riding.



a) Connection screen **(b) Login screen** **(c) Number screen**

(d) Register screen **(e) Main screen** **(f) Riding screen**

Fig. 6. Application display results.

3.5. Results of drowsiness detection test

Drowsiness detection test was done by calculating the heart rate of 30 respondents. The results are shown in Table 11. It presents that the accuracy of sleepiness detection calculations reached 80% following the formula stated by the expert doctor. The accuracy rate during the day only reached an accuracy value of 75%. While the accuracy at night is 90%.

Table 11. Results of drowsiness detection test.

No.	Age	Time	Normal Heart Rate	Heartbeats While Drowsy	Result
1	21	10:13	80	59	Corresponding
2	22	10:15	81	63	Corresponding
3	21	10:17	82	69	Not Corresponding
4	23	10:20	79	57	Corresponding
5	22	10:22	80	67	Not Corresponding
6	22	12:43	75	67	Not Corresponding
7	22	12:46	82	65	Corresponding
8	22	12:48	87	66	Corresponding
9	20	12:50	86	58	Corresponding
10	24	12:54	85	59	Corresponding
11	22	13:05	86	62	Corresponding
12	24	13:08	75	68	Not Corresponding
13	21	13:11	80	66	Not Corresponding
14	23	13:13	81	63	Corresponding
15	23	13:16	87	56	Corresponding
16	21	15:25	83	57	Corresponding
17	21	15:27	82	55	Corresponding
18	22	15:30	88	70	Corresponding
19	23	15:33	81	61	Corresponding
20	20	15:36	89	60	Corresponding
21	20	19:45	78	60	Corresponding
22	22	19:49	82	61	Corresponding
23	22	19:54	89	57	Corresponding
24	22	19:58	84	60	Corresponding
25	24	20:05	88	60	Corresponding
26	22	03:04	80	69	Not Corresponding
27	21	03:07	86	60	Corresponding
28	20	03:09	83	61	Corresponding
29	23	03:13	79	58	Corresponding
30	24	03:16	87	55	Corresponding

3.6. Results of Drowsiness while Riding Test

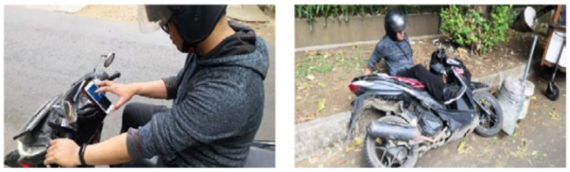
We tested drowsiness while riding a motorbike by cyclically calculating the heart rate with a regular rate of 80. The results of it are shown in Table 12. From the five times test, the alarm on smartphone and vibration on smartband function well when it detects drowsiness.

Table 12. Test results drowsiness while riding.

	Heart Rate	Vibrate Smartband	Vibration and Sound
Test 1	59	Yes	Yes
Test 2	61	Yes	Yes
Test 3	57	Yes	Yes
Test 4	60	Yes	Yes
Test 5	65	Yes	Yes

3.7. Results of Accident Detection Test

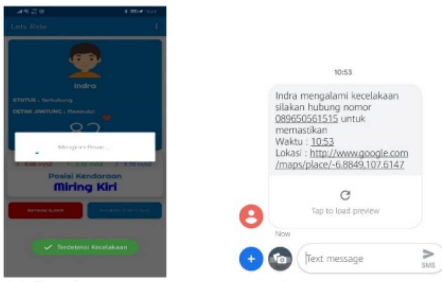
Accident test detection calculates the accelerometer sensor in a smartphone. Figure 7(a) shows the smartphone position on the speedometer for obtaining motor vehicle accelerometer data, and Fig. 7(b) shows the driver has an accident. Moreover, the application sends information to the rider's family that an accident has occurred.



(a) smartphone position. **(b) accident position.**

Fig. 7. Accident detection test.

When an accident is detected, the application will send information in the form of a short message service to the registered destination number. The information sent contains name, the phone number that can contact, time, and coordinates of the accident's location. Figure 8(a) is the display when the application sends a message, while Fig. 8(b) is the result of the short message service that has been sent.



(a) Sending message **(b) Message content**

Fig. 8. Sending information when accident.

Tests accident detection conducted six times as shown in Table 13.

Table 13. Accident detection tests.

Position	Accelerometer Value	Message	Information
Tilt Left	X-axis: 8.66 m / s	sent	Detected Leaning Left
Tilt Right	X-axis: -7.79 m / s	sent	Detected Leaning Right
Tilt Left	X-axis: 7.56 m / s	sent	Detected Leaning Left
Tilt Right	X-axis: -8.16 m / s	sent	Detected Leaning Right
Tilt Left	X-axis: 8.66 m / s	sent	Detected Leaning Left
Tilt Right	X-axis: -8.17 m / s	sent	Detected Leaning Right

The experiment detected the accident and information messages sent to the destination number. These results mean that the level of accuracy in accident detection gets an accuracy rate of 100%. The overall results of the tests conducted on the application of functional aspects of suitability testing, compatibility, usability, and efficiency criteria as shown in Table 14.

Table 14. Software testing result.

	Score	Result
Suitability	100 %	Very decent
Compatibility	100 %	Very decent
Usability	84.71 %	Very decent
Efficiency	3.88 seconds	Satisfied

4. Conclusion

This research has successfully used accelerometer sensors on smartphone Android and wearable devices to detect and prevent motorbike driver accidents. The results of tests carried out showed that the accuracy of detecting drowsiness is equal to 80% and the accident detection test gets an accuracy of 100 %. From the results of software testing also get good grades according to the criteria of suitability, compatibility, usability, and efficiency. The difference in accuracy when detecting drowsiness during the day and night becomes a subject for further research.

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Nomenclatures

A_{BL}	Boolean value when the tilt motorcycle
H_{beat}	Heartbeats value when drowsy
N_{beat}	Normal heartbeats value
X_{axis}	Value on the x-axis accelerometer

Abbreviations

BPM	Beats Per Minute
BPS	*Badan Pusat Statistik*
LED	Light Emitting Diode
NTSC	National Transportation Safety Committee
SMS	Short Message Services
UNIKOM	Universitas Komputer Indonesia

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