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Motorcycle Accident Detection Using Gyroscope, Pulse Sensor, and Global Positioning System Based on Internet of Things with WhatsApp Application

Rafidal Muhammad[1], Mario Jonatan[1], Ayumi Cindy Capela[2], Fajar Kurnia[3], Ferry Hadary[*,1]
Teknik Elektro[1], Rekayasa Sistem Komputer[2], Teknik Mesin[3] – Universitas Tanjungpura
Tajungpura, Indonesia
*ferry.hadary@invent.untan.ac.id

Abstract – *Traffic accidents are one of the leading causes of death in Indonesia. In 2022, there were 94,617 traffic accident cases recorded across the country, resulting in 28,131 fatalities. Motorcycles were involved in 73% of these cases. To reduce the number of motor vehicle accident fatalities, a detection system is needed that can provide real-time accident alerts, location data, and victim health information from distances. The design of this system includes an accident detection device placed on the vehicle and a heart rate detection device in the form of gloves. The accident detection system uses an ESP32 microcontroller, a Gyro MPU6050 sensor, and a GPS NEO6MV2 sensor. It detects accidents based on tilt data and sudden braking. Accident information is sent via WhatsApp chatbot, including the accident location coordinates. Tests showed an average tilt reading difference of 1.34°, an accelerometer reading of 1.89 m/s², and GPS coordinates with an 8.2-meter range. The heart rate detection system uses an ESP32 microcontroller and a MAX30102 heart rate sensor. It sends alerts via WhatsApp chatbot when the user's heart rate is abnormal. Tests showed an average heart rate reading difference of 11.75 bpm.*

Keywords – *Accident detector; chatbot; gyroscope; Global positioning system; Pulse sensor.*

I. Introduction

TRAFFIC accidents are one of the leading causes of death in Indonesia. During the period from January 2022 to September 13, 2022, based on reports from the Indonesian National Police Traffic Corps (Korlantas Polri), a total of 94,617 traffic accident cases were recorded across the Republic of Indonesia. From these cases, fatalities reached a significant figure of 28,131 lives lost in 2022 [1]. Motorcycle accidents dominate traffic incidents. According to accident data by vehicle type, motorcycles are involved in 73% of traffic accidents, followed by freight transport vehicles at 12% [2].

The high number of motorcycle accidents is very concerning, contributing significantly to traffic fatalities, especially since motorcycles have limited safety features compared to other modes of transportation such as cars who had a lot of research contributed around accident detection [3–5]. Therefore, serious efforts are needed to reduce accident-related deaths, including designing a real-time accident detection system for motorcycles. Such a system must also be able to provide location and victim condition information remotely, in order to facilitate faster rescue efforts and minimize fatalities [6].

The design of such a system requires consideration parameters that can distinguish between normal vehicle operation and accident conditions. Many researchers chose to identify it with complex AI algorithms [7, 8]. However, the system needs to act in real time, hence it requires minimal computation. Which is why in this study, accident indicators are based on motorcycle tilt and acceleration, measured using the MPU6050 accelerometer and gyroscope [9, 10]. The MPU6050 sensor is used to measure and maintain acceleration as well as motion orientation, relying on a rapidly rotating disk along its axis [11]. Motorcycle accidents can be detected by utilizing angles measured by a three-axis gyroscope sensor. When the sensor detects a tilt angle that exceeds a predefined threshold followed by a sudden decrease in acceleration, it may indicate the motorcycle has fallen due to an accident [12].

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An effective accident detection system should be capable of sending notifications to relevant parties (such as family, vehicle owners, or medical personnel). For this reason, a motorcycle accident detection system should be integrated with Internet of Things (IoT) technology, which enables accident alerts to be transmitted via the internet [13, 14]. To further support emergency response, a navigation system such as GPS is essential to provide precise accident location information [15, 16]. GPS is a satellite-based navigation system capable of providing real-time positional and time information anywhere on Earth, under any weather conditions. The data transmitted by GPS satellites include latitude and longitude coordinates, which can be integrated into vehicle security systems to send location into smartphone devices [17, 18].

Victim health condition is another critical factor for accident response. The addition of a pulse sensor, such as the MAX30102 [19], enhances the usefulness of the detection system. The pulse sensor is essentially a photoplethysmograph (PPG) that works by detecting variations in light intensity. In medical applications, PPG is widely used for monitoring respiration and heart rate [20]. In this study, the pulse sensor is used to detect sudden changes in the rider's heart rate, which may occur when the gyroscope detects abrupt changes in tilt or acceleration caused by an accident [21].

The proposed motorcycle accident early warning system is built using an ESP32 microcontroller, MPU6050 gyroscope, NEO6MV2 GPS, and MAX30102 pulse sensor. This system combines previous studies on accident detection systems using angle and acceleration measurement [9–12], GPS coordinates sent through IoT integration [13–18], as well as pulse measurement to detect victim condition [19–21]. This system is capable of detecting accidents and leverages the potential of IoT, where devices can communicate via the internet. With IoT integration, accident information can be sent in real time through the WhatsApp application, thus reducing response time and improving rider safety while minimizing the risk of severe injury.

Parameters measured for accident detection by this system include sudden change in angle and acceleration. After the accident has happened and the location has been sent, the pulse sensor will send an additional notification once the victim's heart rate reaches a critical condition. In addition to previous literature, this research also calculates the error for each parameter measurement by the proposed system and simulates the accident condition to prove the system's reliability. The proposed system should have minimum error in measurement, correctly identify the accident condition, and send alerts as well as accident coordinates through WhatsApp notification.

II. Research Methods

The literature study in this research was conducted by collecting data from previous studies through journals, books, articles, and other relevant documentation to support the development of the proposed system. Following this, a design concept was created by identifying system requirements and functional specifications to determine the most suitable prototype design.

i. Device Development

The system was designed to meet the following criteria: the ability to detect vehicle tilt and acceleration, monitor the rider's heart rate, connect to the internet, operate using an external power source, and maintain a compact size. Two main observation targets were established: (1) mechanical parameters, including vehicle tilt and acceleration, and (2) biological parameters, specifically the rider's heart rate.

The prototype consists of two components: a motorcycle accident detection device and a heart rate monitoring device. The accident detection device has a rectangular shape with dimensions of 8×6 cm^2, as shown in Figure 1. On the front panel, the device includes a GPS antenna and two indicator LEDs (red and green). The internal circuit board integrates the microcontroller, GPS module, and gyroscope sensor. The prototype is mounted on the motorcycle frame. Meanwhile, the heart rate monitoring device consists of an Arduino-based circuit with a pulse sensor attached to the rider's glove.

Both devices are connected to the internet and capable of sending accident alerts via WhatsApp messages to a designated recipient. System block diagram is illustrated in Figure 2.

A 3D model of the prototype housing was designed using Fusion 3D software. The housings for both the accident detection device and the heart rate monitoring device were fabricated using 3D printing with a thickness of 1 mm, as shown in Figure 3. In addition, circuit boards for both devices were designed using the EasyEDA platform. The printed circuit boards (PCBs) were double-layer designs, with schematic diagrams shown in Figure 4. The final assembled prototypes are displayed in Figure 5.

ii. Testing Method

Once assembled, the prototypes were tested to ensure functionality and accuracy in measuring the required parameters. The variables evaluated were:

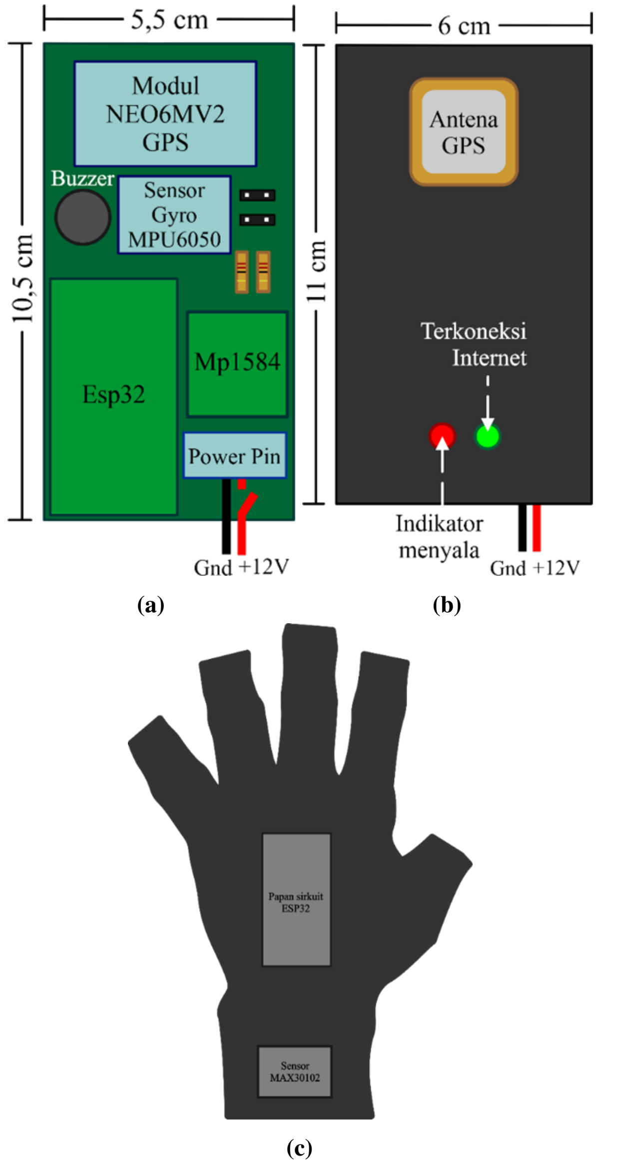


Figure 1: (a) Accident detection system design; (b) Indicator lamp; and (c) Heartbeat detection design

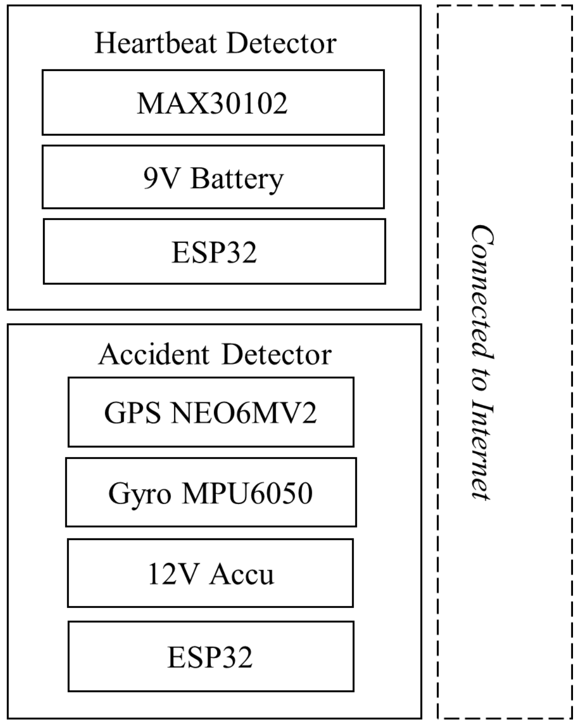


Figure 2: The system block diagram

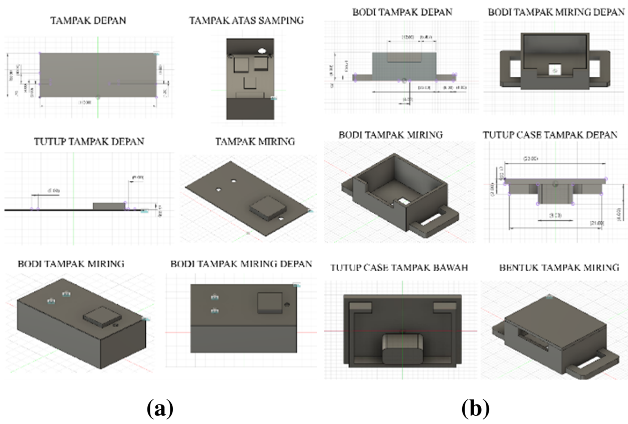


Figure 3: System 3D design.

1. Accuracy of vehicle tilt measurement;
2. Vehicle acceleration;
3. GPS coordinates; and
4. Rider's heart rate (beats per minute).

The testing procedure was conducted under the following conditions:

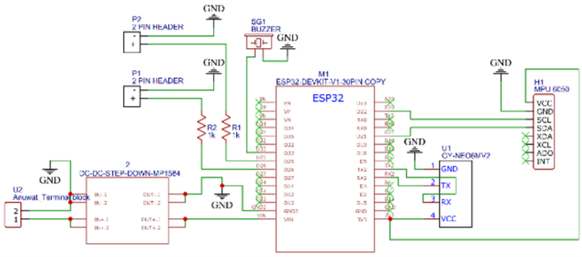
1. The accident detection prototype was mounted on a custom steel plate bracket attached to the motorcycle, while the heart rate monitoring prototype was placed on the rider's glove, as shown in Figure 6;
2. Measurement values were transmitted via WhatsApp chatbot messages to the user; and
3. The accident detection device was powered by the motorcycle's battery, while the heart rate monitoring glove was powered by a 160 mAh 3.7 V LiPo battery connected in series.

For validation, each measured variable was compared against standard measurement devices. Tilt and acceleration readings from the gyroscope sensor were validated against a smartphone's built-in sensors. GPS coordinates were compared with those obtained from Google Maps. Heart rate measurements from the pulse sensor were compared against a pulse oximeter. This method was only used to test the system in a controlled condition and not in a real accident. However, the data can be used to judge the proposed system accuracy for further implementation.

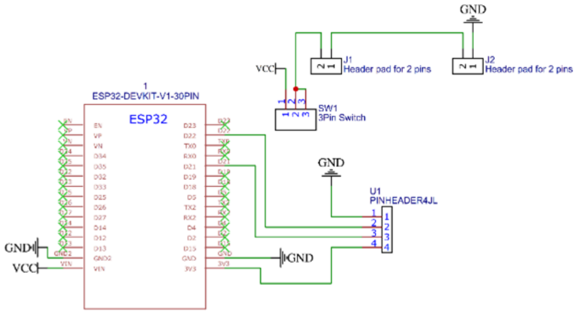
III. Results and Discussion

i. *Tilt Detection Test*

Tilt detection testing was carried out 10 times, and the results are presented in Table 1. Based on the test



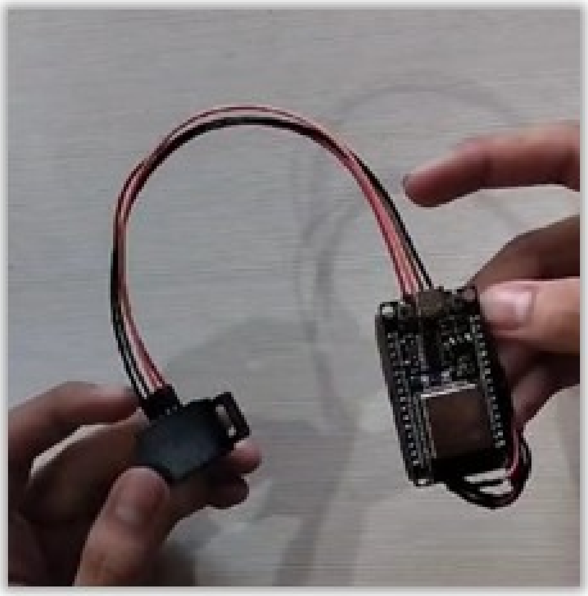
(a)



(b)

Figure 4: Electrical schematic diagram for (a) accident detector and (b) heartbeat detector.

(a)



(b)

Figure 5: Final prototype for (a) accident detector and (b) heartbeat detector

outcomes, the average difference value was calculated to be 1.345°, with an average error of 3.27%. This error rate is relatively small and demonstrates that the gyroscope sensor is reliable enough to serve as one of the indicators for motorcycle accident detection.

Table 1: Tilt detection test result

No	Actual gyroscope readings	Prototype readings	Error
1	-40.00°	-40.04°	0.04
2	-39.00°	-40.00°	1.00
3	-41.00°	-40.00°	1.00
4	-42.00°	-40.02°	1.98
5	-41.00°	-40.01°	0.99
6	42.00°	40.02°	1.98
7	41.00°	40.01°	0.99
8	42.00°	40.00°	2.00
9	42.50°	40.00°	2.50
10	41.00°	40.03°	0.97

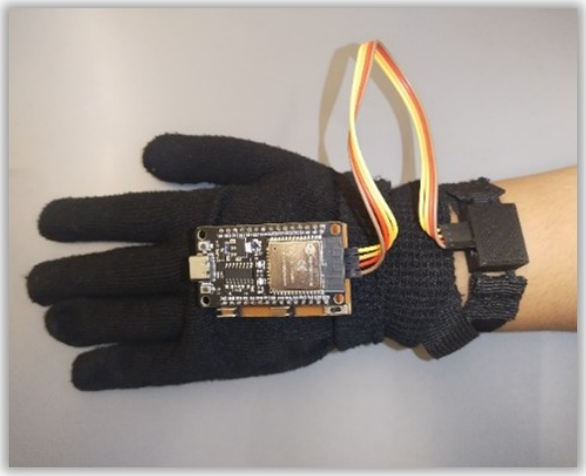
ii. Acceleration Detection Test

Acceleration detection testing was also conducted 10 times, with results shown in Table 2. The average difference value obtained was 1.89 m/s^2, while the average error was 9.57%. This error level is still considered acceptable and sufficient for use as an indicator of sudden deceleration events that may indicate a motorcycle accident.

Table 2: Acceleration detection test result

No	Actual accelerometer readings	Prototype readings	Error
1	-19.50 m/s^2	-19.15 m/s^2	0.35
2	-19.75 m/s^2	-18.11 m/s^2	1.64
3	-19.15 m/s^2	-17.84 m/s^2	1.31
4	-19.35 m/s^2	-17.17 m/s^2	2.18
5	-19.80 m/s^2	-18.35 m/s^2	1.45
6	-19.50 m/s^2	-18.35 m/s^2	1.15
7	-19.53 m/s^2	-17.15 m/s^2	2.38
8	-20.00 m/s^2	-18.27 m/s^2	1.73
9	-21.14 m/s^2	-17.07 m/s^2	4.07
10	-19.72 m/s^2	-17.08 m/s^2	2.64

(a)



(b)

Figure 6: Prototype placement for (a) accident detector and (b) heartbeat detector

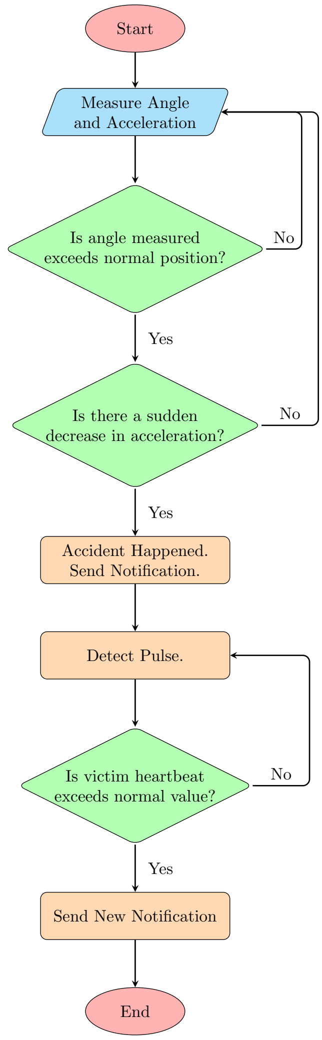


Figure 7: System algorithm

iii. GPS Coordinate Detection Test

GPS coordinate detection testing was performed 10 times, and the results are summarized in Table 3. The average difference in distance compared to the reference was found to be 8.2 meters. This level of accuracy is sufficient for practical application in determining the accident location of the rider.

Table 3: GPS coordinate detection test result

No	Actual location	Prototype readings	Error
1	-0.0612274°, 109.3545192°	-0.061269°, 109.354568°	6 m
2	-0.057228°, 109.351558°	-0.057597°, 109.351578°	15 m
3	-0.0646932°, 109.3400299°	-0.064669°, 109.340119°	11 m
4	-0.0668319°, 109.3411581°	-0.066812°, 109.341164°	2 m
5	-0.0564042°, 109.3446416°	-0.056389°, 109.344633°	3 m
6	-0.0897668°, 109.3923804°	-0.089670°, 109.392457°	15 m
7	-0.0526507°, 109.3608113°	-0.052585°, 109.360823°	6 m
8	-0.0567787°, 109.3472661°	-0.056721°, 109.347264°	6 m
9	-0.0653403°, 109.3637597°	-0.065420°, 109.363653°	15 m
10	-0.0563358°, 109.3474767°	-0.056342°, 109.347499°	3 m

iv. Heart Rate Detection Test

Heart rate detection testing was conducted 20 times, and the results are displayed in Table 4. The average difference in heart rate readings compared to the reference device was 11.75 bpm, with an average error of 13.41%. Although this error rate is relatively high compared to the other parameters, the sensor performance is still considered usable as a supporting indicator.

v. Accident Detection Simulation

After validating the accuracy of the four sensors, accident simulation tests were conducted. The following scenarios were evaluated:

1. Motorcycle falls while stationary — tilt detected but no alert sent.
2. Motorcycle stops suddenly but remains upright —

Table 4: Heartrate detection test result

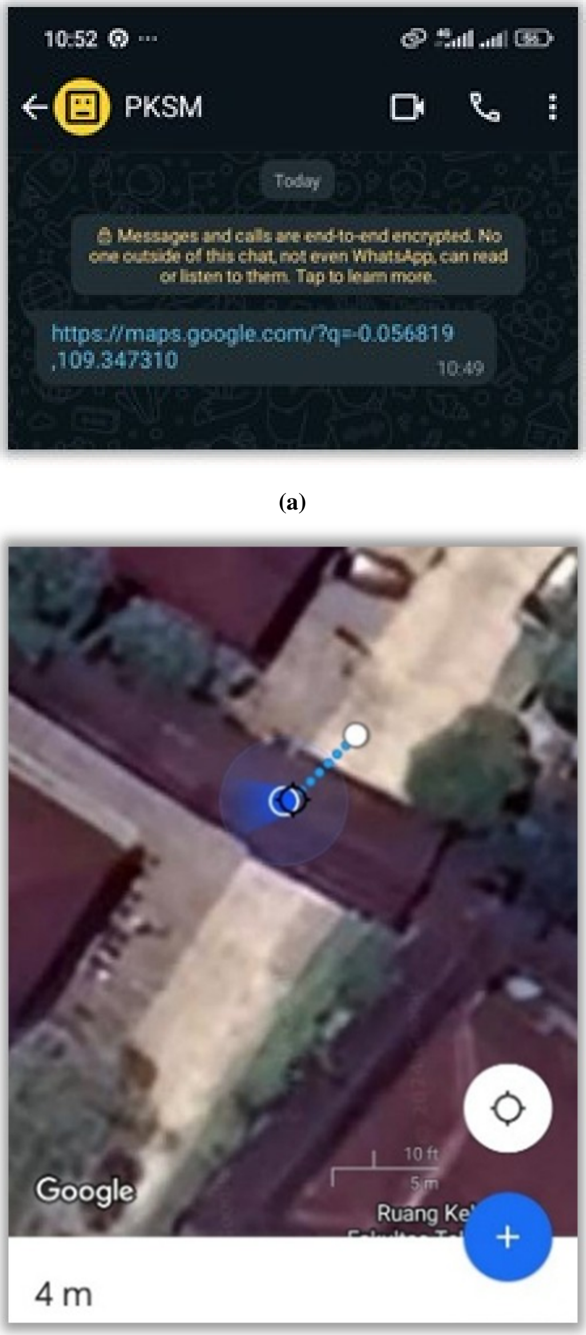
No	Actual heartbeat	Prototype readings	Error
1	92 bpm	90 bpm	2
2	93 bpm	85 bpm	8
3	95 bpm	89 bpm	6
4	97 bpm	86 bpm	11
5	96 bpm	85 bpm	11
6	89 bpm	82 bpm	7
7	87 bpm	75 bpm	12
8	87 bpm	72 bpm	15
9	88 bpm	82 bpm	6
10	90 bpm	89 bpm	1
11	79 bpm	65 bpm	14
12	80 bpm	75 bpm	5
13	81 bpm	69 bpm	12
14	82 bpm	57 bpm	25
15	81 bpm	50 bpm	31
16	91 bpm	77 bpm	14
17	89 bpm	71 bpm	18
18	89 bpm	71 bpm	18
19	84 bpm	71 bpm	13
20	82 bpm	76 bpm	6

deceleration detected but no alert sent.

3. Motorcycle accident while in motion — tilt and deceleration detected simultaneously; system successfully sent an alert with GPS coordinates via WhatsApp chatbot.

Figure 8: Notification sent when motor is tilted and sudden de-acceleration happen

The simulation results, illustrated in Figure 8, confirm that the prototype system can distinguish between normal riding conditions and actual accident scenarios. The ability to send real-time accident notifications along with location information via WhatsApp demonstrates the practical feasibility of the developed



(a)

(b)

Figure 9: Simulation location and gps coordinate sent

IoT-based motorcycle accident detection system.

This study contributes to the body of knowledge on intelligent transportation systems by demonstrating how a multi-sensor fusion approach can improve the reliability of accident detection in motorcycles. The study shows that accident detection can be achieved with relatively simple, low-cost sensors while still maintaining acceptable accuracy. This finding supports the notion that lightweight IoT-based methods can serve as an alternative to more complex artificial intelligence or image-based approaches, thereby filling a gap in the literature regarding accessible accident detection systems for resource-constrained environments.

From a practical perspective, the prototype developed in this study provides a viable solution for enhancing motorcycle safety in regions where such vehicles dominate traffic and accident rates remain high. The implementation of real-time WhatsApp notifications ensures that accident alerts can reach families or emergency responders quickly, without requiring specialized infrastructure. Furthermore, the integration of heart rate monitoring extends the functionality of existing detection systems by providing additional information about the rider's condition, which can aid emergency response decision-making. This suggests that the system has potential for large-scale adoption, particularly in developing countries where affordability and ease of deployment are critical factors.

IV. Conclusion

The development of an effective accident detection system for two-wheeled vehicles is essential to reduce traffic-related fatalities caused by delayed emergency response. The proposed system integrates an ESP32 microcontroller with MPU6050 gyroscope, NEO6MV2 GPS, and MAX30102 pulse sensor to detect and notify motorcycle accidents.

Testing results demonstrated relatively small errors in three parameters: tilt (3.27%), acceleration (9.57%), and GPS (8.2 m). For heart rate, the error was higher (13.41%), but still useful. Simulation trials validated the system's functionality in distinguishing accident scenarios and successfully delivering WhatsApp notifications with coordinates. Further improvements should aim to reduce errors, but even with low-cost components, the purpose of accident detection and alerting is achieved.

Acknowledgment

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