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A prototype of IoT-based smart system to support motorcyclists safety

A prototype of IoT-based smart system to support motorcyclists safety

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Abstract. This study described the prototype of the smart system for support safety riding using the Internet of Things (IoT) technology. This system consists of connectivity objects like helmets, motorcycles, and riders/people (via smartphone). The system is pervasive in helmets and motorcycle with several main electronic components, including NodeMCU micro controller, accelerometer-gyroscope sensor, a GPS (Global Positioning System) module, flex sensor, buzzer, and relay. The helmet, motorcycles, and riders then are connected with others through the internet with the android application interface. The application can monitor real-time status and location riders using firebases's real-time database. This system has four features, which are a combination of previous related works, namely helmet detection, drowsiness detection, accident detection, and notification with the accident's location that can be tracked by others. The results of this system prototype experiment showed that all features of the system are running well. The accuracy value for helmet detection is 100%, drowsiness detection is 87%, and accident detection is 90%. Rider status and location can be monitored and tracked by others via the android application.

1. Introduction

The worldwide status report on road safety in 2018, distributed by WHO in December 2018, features that the quantity of yearly road traffic deaths has come to 1.35 million with the most victims are motorcyclist. Head injuries are the leading cause of death and major trauma. Liu et al. in [1] conveying that the correct use of helmets can lead to a 42% reduction in the risk of fatal injury and a 69% reduction in the risk of head injury. The utilize of a standard helmet is critical implies to anticipate the deaths occurs in traffic accidents.

The Indonesian government has made a law concerning road traffic and transport [2] in Article 57 Paragraph 2 states that the Indonesian National Standard helmet (SNI) is standard equipment for the motorcyclist. Article 106 Paragraph 8 of the Law, also states that every motorcyclist must use a SNI helmet. Then it is followed up on article 283 that any person who rides a motorcycle on the road improperly and does other activities or is affected by a condition that causes concentration disturbances in riding will be subject to sanctions.

Five main innovations that support the improvement of the Industry 4.0 framework in Indonesia are the Internet of Things (IoT), Artificial Intelligence, Human-Machine Interface, robotics and sensor technology, and 3D printing technology [3]. IoT carries the concept of connectivity of objects using the internet. Coetzee and Eksteen in [4] connectivity is improved from "anytime, anywhere" for "anyone" to "anytime, anywhere" for "anything". IoT by Patel and Patel [5] is connectivity to the internet among objects: people with people, people with machines, and machines with machines, which are pervasive, with wired or wireless connections and addressing schemes that is unique for creating applications or services with specific goals.

There are a few past articles or previous related works that have discussed smart systems using helmets as a safety equipment with the following intelligence:

1) Forcing the rider to wear a helmet, otherwise the motorcycle engine cannot be started [6, 7, 8, 9, 10, 11, 12, 13, 14]
2) Give the rider a warning when drowsy [15]
3) Detect accidents and provide notifications with locations that can be tracked [16, 17, 18]

References [16] Chandran, Chandrasekar, and Elizabeth focused on making smart helmets with features to detect accidents and provide notification to other entities. They used a 3-axial BMA222 accelerometer to check the three orthogonal spatial components of the x, y, z directors of the helmet. Accidents occured when there are shocks/collisions that cause changes in the value of the threshold that has been determined from the x, y, z helmet. The GPS module and the CC3200 microcontroller wireless were used to process the condition of the change in value as an accident along with its latitude and longitudinal location sent to the cloud-based web service. Notification of an accident via email / SMS to other entities along with its location using the PagerDuty REST API.

References [17] Shabbeer and Meleet used the MPU6050 6-axis accelerometer and gyroscope sensor to determine the accident by looking at the slope of the motor and in determining the accident's location using the NEO6M V2 GPS Module and tracking the accident location using the Google Maps API. They used the Arduino Uno microcontroller with Sim900 GSM Module for internet connectivity with the webserver. Notifications were sent to other entities via email.

References [18] Lekha et al. detected accidents using a vibrator sensor in the presence of shocks to the helmet. NEO6M V2 GPS Module was used to provide latitude and longitude information on the accident's location so that it can be tracked with the help of google maps. Notification to other entities was sent via SMS.

Public awareness to comply with traffic laws can be helped by the existence of a smart helmet that has several functionalities, including being obliged to wear a helmet and not riding when tired/drowsy or intoxicated. This is in order to prevent or reduce the higher accident rate. When an accident occurs, it should be able to be treated quickly to decrease the death rate. This can also be helped by IoT technology, where entities are connected to one another. The expectation is that if there is an accident, it can be quickly handled by others. In the smart helmet feature of accident detection and notification along with the coordinates of the accident location that can be tracked.

This article discussed a prototype of a smart system that uses IoT technology. It was organized as follows: Section 2 presents the prototype design. Section 3 offers result and discussion, and finally, this research work is concluded in Section 4. This system involved objects such as helmets which are standard equipment, motorcycles and people (via smartphones). They were connected in both wired and or wireless networks in an application or system. This system was designed to support motorcyclist safety. The development of previous work was that this system combined several features from previous works: (1) helm detection, (2) drowsiness detection, (3) accident detection and notification, (4) location tracking. Previous works used a third party: PagerDuty and Email or SMS for notification and share location while the system in the present study used an Android-based application.

2. Prototype Design

The System applied the Internet of Things (IoT) technology using the realtime database firebase platform and wireless microcontroller nodeMCU. The objects (motors, helmets, and riders) were connected in the internet network with the firebase and nodeMCU platforms. This design was illustrated using a system architecture, component block diagrams, and program pseudocode.

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2.1. System architecture
The IoT-based system architecture shown in Figure 1 is a network between objects (helmets, motorcycles, riders) on the Firebase and NodeMCU platforms.

Figure 1. System architecture.

NodeMCU microcontrollers, sensors and other electronic components were embedded in helmets and motorcycles. They wereused to sense/record data using a helmet or not, drowsy or not, rider status: safe or danger (accident) and accident location: latitude and longitude. These data were received and realtime updated on Firebase, which can then be accessed for monitoring via the android application on a smartphone. Electronic components embedded in the helmet and motorcycle were supplied with a power supply from a lithium-ion battery. The WiFi network used by nodeMCU was a hotspot network of smartphones.

2.2. Embedded in helmet
Figure 2 shows a block diagram of the electronic component that embedded in the helmet.

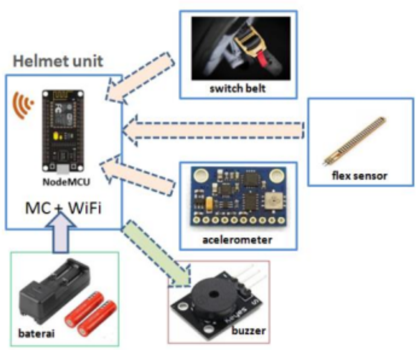

Figure 2. Block diagram of electronic devices at helmet unit.

On the helmet, there was a microcontroller, switch belt, accelerometer gyroscope sensor, flex sensor, buzzer, and power supply. The microcontroller component used NodeMCU to process the input data from the accelerometer sensor and switch belt as a trigger to turn on the actuator. The relay on the motorcycle through firebase became actuators from the switch belt and flex sensor. If the riders do not use helmet and switch belt properly, the relay disconnected the motor ignition. Buzzer became an

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accelerometer actuator when it was detected drowsiness with a predetermined slope, is considered to be drowsy. Some DC battery supplied all electronic components.

2.3. Embedded in motorcycle

Figure 3 shows a block diagram of electronic components embedded in the motorcycle.

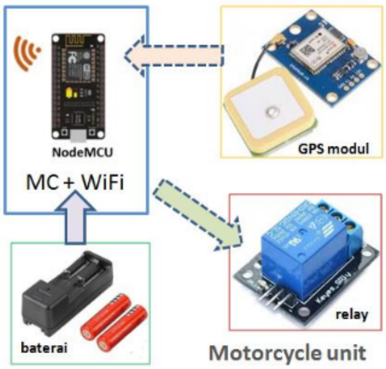

Figure 3. Block diagram of electronic device at motorcycle unit.

On a motorcycle, there were NOdeMCU microcontroller, GPS module, relay and power supply. The GPS module used UBLOX NEO-6M V2 GY-GPS6MV2, to record the latitude and longitude of the accident location. When the accelerometer GY-521 MPU6050 3-AXIS on a helmet detected a shock or accident, the system sent location data to Firebase and notified other users. Other users through the android application can track the accident's location.

2.4. Pseudocode of program

Coding of system functionality in the microcontroller sub-system used the Arduino IDE. Figure 4 shows pseudocode to ensure the engine functions when wearing a helmet belt.

```
//helmet unit
belt = digitalRead(switch);
flex = digitalRead(press);
  if(belt == HIGH && flex >= 330):
  | Firebase setString switch_belt, "on"
  | status = 1
    else:
    | Firebase setString switch_belt, "off"
    | status = 0
//motorcycle unit
if (firebase switch_belt == "on")
  digitalWrite relay, HIGH
  else
    digitalWrite relay, LOW
```

Figure 4. Pseudocode to ensure wearing the helmet.

Figure 5 shows the pseudocode to detect that rider is drowsy and gives a warning with a buzzer.

```
//helmet unit
declare Ax, Ay, Az
Ax = (double)AccelX/AccelScaleFactor;
Ay = (double)AccelY/AccelScaleFactor;
Az = (double)AccelZ/AccelScaleFactor;
//drowsiness value
if(Ax<0.25 && Ay<-0.55 && Az>-0.90):
  digitalWrite buzzer,HIGH
  else
    digitalWrite buzzer,LOW
```

Figure 5. Pseudocode to detect drowsiness.

Drowsiness and danger values in this MPU were obtained by taking the average of the test sample many times when there was suddenly nod and bump or shaking. Then the pseudocode to detect the accident and give the rider status notification can be seen at figure 6.

```
//helmet unit
declare Gx, Gy, Gz
Gx = (double)GyroX/GyroScaleFactor
Gy = (double)GyroY/GyroScaleFactor
Gz = (double)GyroZ/GyroScaleFactor
//fall down value
if(Gx>150 || Gy>150 || Gz>150):
    Firebase setString status, "danger"
```

Figure 6. Pseudocode to detect accident.

Here is figure 7, pseudocode to retrieve the coordinates of the accident and update it on Firebase:

```
//motorcycle unit
declare TinyGPSPlus gps
initialize SoftwareSerial ss
if (ss available data):
| if (gps encode ss read):
| | if (gps location isValid):
| | | get latitude
| | |   get longitude
| | |   lat_long = latitude + longitude
Firebase setString lat_long
```

Figure 7. Pseudocode to retrieve the coordinates of the accident's location.

The prototype of the system designed was a miniature for testing and implementing IoT technology by using an open-source and free platform. For motorcycle, it used a mini replica, where the ignition engine was likened to a dc motor. GPS modules were embedded on a motorcycle on the reason that motorcycle is more expensive than a helmet, with the consideration that if a motorcycle is stolen, it can be tracked too.

3. Result and Discussion

3.1. Result

The functionality of this helmet has been tested. The belt switch was designed by using a copper wire connection through the helmet belt. The connection made conditions on like a switch, meaning the helmet was used properly. And then the flex sensor ensured the helmet was used by the rider. The electronic component was embedded on the helmet, so that it is pervasive, integrated into the helmet

Figure 8. Electronic devices embedded at helmet unit.

The prototype to show the system can run on a motorcycle using a mini replica. The dc motor was used as a substitute for the ignition engine. The DC motor was disconnected by a relay contact ignited from the NodeMCU microcontroller. GPS modules were installed on the motorcycle, as shown in Figure 9.

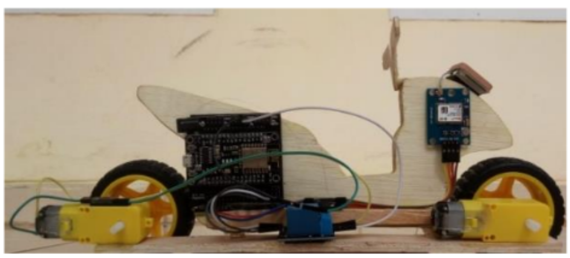

Figure 9. Electronic devices embedded on motorcycle unit.

Helmet switch belt functionality testing aimed to fasten the helmet strap properly so the engine can start. This test was carried out 60 times. When the helmet strap is not fastened, the engine will not start and to ensure the helmet used by the rider, a flex sensor was added. The helmet was worn when the flex sensor value is above or equal to 330 [19]. Table 1 shows the helmet detection test results.

Table 1. The helmet detection test result.

Condition of helmet	Average flex value	Switch belt	Expected detection	System detection
Being worn	336	on	True	True (10 from 10 testing)
Being brought	294	on	False	False (10 from 10 testing)
Being hanged	309	on	False	False (10 from 10 testing)
Being worn	335	off	False	False (10 from 10 testing)
Being brought	292	off	False	False (10 from 10 testing)
Being hanged	307	off	False	False (10 from 10 testing)

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The drowsiness detection test was carried out 30 times. When the helm was positioned nodded suddenly (drowsy), the buzzer sounds to warn the rider. The drowsiness detection test results can be seen in Table 2.

Table 2. The drowsiness detection test result.

Condition of helmet on head	Average accelerometer value			Expected detection	System detection
	Ax	Ay	Az		
Suddenly nod	0.20	-0.60	-0.85	True	True (8 from 10 testing)
Not move	0.35	0.10	0.65	False	False (10 from 10 testing)
Shake right-left	-0.44	-0.46	0.55	False	False (8 from 10 testing)

Testing for accident detection was by dropping the helmet so it will notify the rider's status as "danger". The accident detection test results can be seen in Table 3.

Table 3. The accident detection test result.

Condition of helmet on head	Average gyroscope value			Expected detection	System detection
	Gx	Gy	Gz		
Fall down	154	158	160	True	True (9 from 10 testing)
Shake	147	146	120	False	False (8 from 10 testing)
Not move	30	25	-20	False	False (10 from 10 testing)

The rider status shown in Figure 10 are friends seen in the nearest google map. If a friend has an accident, there is a notification, and the location of the incident can be traced.

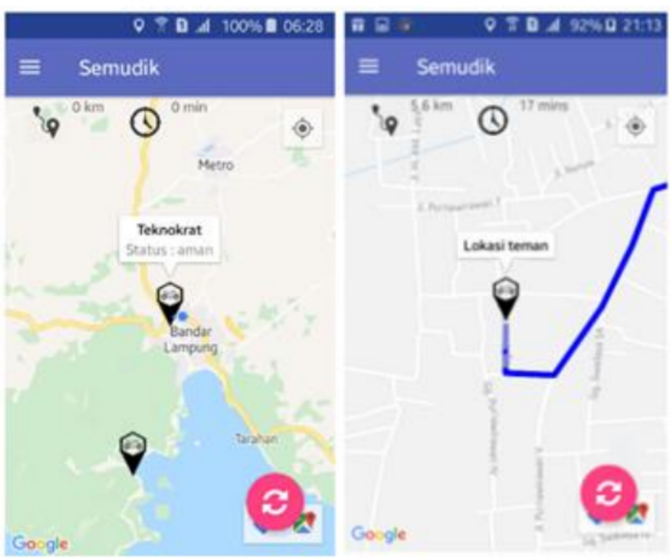

Figure 10. Rider status and tracking rider's location at Android App.

3.2. Discussion
Table 1 provides information that the accuracy of wearing a helmet using a flex sensor and a switch belt is very satisfying, which is 100%. Based on table 1, the accuracy value of the detection of helmet use can be calculated.

$$accuracy\ helmet\ detection = \frac{60}{60}\ x\ 100\% = 100\% \quad (1)$$

From the experiments, everything was as expected, and the system worked well. The use of a flex sensor and a switch belt is very helpful in ensuring the rider is wearing the helmet properly. If the rider does not wear the helmet properly by tightening the switch belt, the motorcycle engine will not start, even though the helmet is in use. This case can be seen from the row of the switch-belt column is off.

The drowsiness detection accuracy, according to Table 2, is 87%, in accordance with the following calculation:

$$accuracy\ drowsiness\ detection = \frac{26}{30}\ x\ 100\% = 87\% \quad (2)$$

This accuracy value is sufficient, but it does not perfectly ensure that the rider is drowsy. Likewise, the accident detection accuracy, according to Table 3, is 90% in accordance with the following calculations:

$$accuracy\ accident\ detection = \frac{27}{30}\ x\ 100\% = 90\% \quad (3)$$

The accuracy of this accident detection is sufficient to indicate that the rider is falling. The system worked well, that is when the helmet was worn properly and then it falls with the rider, system will notify other riders or other people. And then the other people can track the location of the accident based on the notification with latitude and longitude via the android application.

4. Conclusions
The prototype of the smart system has successfully implemented Internet of Things (IoT) technology, which can build connectivity between objects: motorcycle, helmets and riders/others via smartphone for support motorcyclist safety. Four system features have been functionally tested. They are helmet detection, drowsiness detection, accident detection and notification, and tracking location of the accident. The test results are successful and in accordance with how the system works. The accuracy value for helmet detection is 100%, drowsiness detection is 87%, and accident detection is 90%. Rider status and location can be monitored and tracked by others via the android application. This system is helpful for support the safety of the motorcyclist.

Acknowledgments
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