



Implementation of Telegram Notification System for Motorbike Accidents Based on Internet Of Things

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ABSTRACT

In making this final project, it describes in detail the process of designing and building a telegram notification system for motorcycle accidents based on the internet of things. Before designing and building the system, a survey was conducted using the questionnaire and interview methods as the basis for the benchmark in designing and building the system. The purpose of this final project is to design and build a telegram notification system for motorcycle accidents based on the internet of things which is used to make it easier to obtain information when an accident occurs in a quiet place or an area that is common to motorists. The telegram notification system for motorcycle accidents has the main component, namely ESP32 as a microcontroller that can be connected to wifi, the accident detector of this system uses the MPU6050 sensor. The results of this final project, the system can run as expected, at the stage of testing the difference in the GPS comparison obtained can be categorized as successful, and the slope ratio has a difference that is almost the same as the standard clinometer tool, then the comparison of the A3144 sensor there is a difference obtained with the standard tachometer tool. And the system can send notifications when a motorcycle has an accident and the system is able to send information when Telegram users need it.

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1. Introduction

The large number of deaths of motorcyclists, making traffic accidents a problem that is often faced by several big cities in Indonesia, for example in the province of Bali, the Central Statistics Agency (BPS) stated that traffic accidents in 2018 were 1,824 and 482 victims died, in 2019 there were 2,462 and 420 victims died, in 2020 there were 1,787 cases of accidents which resulted in 405 fatalities (Pravalika & Rajendra Prasad, 2019; Thornton, 2021).

Accidents that occur, especially in the province of Bali, are one proof of the development of modern traffic technology, technology makes it easier for people to get motorbikes which are used as a means of transportation every day. According to data on motorcycle sales in Indonesia in 2020, there were 3,660,616 domestic and export motorcycle units (Aji Saputra et al., 2020; Desnanjaya et al., 2020; Furizal et al., 2023).

According to there are several factors that influence the increase in the number of accidents each year (Desnanjaya & Made Aditya Nugraha, 2022; Taştan & Gökozan, 2019). These factors include humans, vehicles, and the environment. Among these three factors, human error is the highest cause of accidents, namely, 86.8% of the total accidents that have occurred. At the time of the accident, the supporting factor for driver safety is by implementing safety riding. Safety riding is a program to reduce the number of traffic accidents. The target of the safety riding program is to equip vehicles

with mirrors, turn signals, and brake lights and use standard helmets (Alsaedi et al., 2020; Parthasarathy et al., 2019; Shafique et al., 2020). Apart from implementing safety riding as the key to motorcyclist safety. Information about accidents experienced by motorists is one of the things that must be considered. According to the results of a survey conducted by researchers to the public using a questionnaire and interview method at Garuz Rent Bike. In the questionnaire stated, everyone has had an accident, and accidents can occur in quiet places which results in accidents not being known by people around resulting in assistance to accident victims being late, and also the community needs technology that can send accident information experienced by riders in real time and the system designed needs to use low-cost technology and the technology is often used by the community, to make it easier to operate the system (Nugraha et al., 2021). Based on the results of interviews obtained from Garuz Rent Bike, it is difficult to find a location when an accident occurs because most of the renters come from outside the area or international tourists (Adhiwibowo et al., 2020; Chamim et al., 2021; Desnanjaya et al., 2021; Husni et al., 2021; Lin et al., 2020).

Based on the above problems, the researcher developed a previous study entitled "Accident Notification System on Arduino-Based Motorcycle" in the study the tool made has features in the form of SMS (Short Message Service) notifications containing accident coordinates. The development carried out by researchers refers to the application of Telegram as a substitute for the SMS function and the addition of the RPM (Revolutions per Minute) counter feature using the A3144 hall effect sensor and the use of NodeMCU ESP32 as the controller (BenSaleh et al., 2020; Desnanjaya & Arsana, 2021; Najmurokhman et al., 2020; Nasir et al., 2020).

The results of this development aim to increase features in order to better assist Garuz Rent Bike, friends, relatives, and family in knowing the location and information of motorbikes when an accident occurs or does not occur through messages received from telegrams.

2. Literature Review

Literature reviews are summaries of multiple pieces of literature that serve as a foundation for this research. Several library sources were consulted for this study. This research designs and implements an Internet of Things-based accident detection and notification system for motorcycles in real time. The system gathers data through the utilization of accelerometer, gyroscope, and GPS sensors (Jauhari et al., 2021; Sudipa et al., 2023). Using a threshold algorithm, accidents are detected. In the event of an accident, the system notifies adjacent smartphone applications of other users as well as a cloud-based platform utilized for data management. An IoT-based motorcycle accident detection and notification system was proposed in another study (Rehman et al., 2021). The system collects data utilizing a gyroscope, GPS, and accelerometer. Using a threshold algorithm, accidents are detected (Alim et al., 2020). The system notifies the web server and smartphone applications of adjacent users in the event of an accident. The subsequent investigation developed a smartphone-based GPS, accelerometer, and gyroscope-based motorcycle accident detection system. An algorithm for machine learning (Random Forest) is implemented to detect accidents from sensor data (Kumar et al., 2020). In the event of a disaster, the system will promptly dispatch an SMS notification to the designated emergency contact. Ongoing research is being devoted to IoT-based motorcycle accident notification systems. Several studies have yielded encouraging findings regarding the enhancement of motorcyclists' safety. Nevertheless, there remain certain challenges that must be resolved, including the precision of accident detection and the utilization of battery power (Goyal et al., 2022; Shubham et al., 2021). The GAP of present study is dedicated to enhancing accident detection capabilities, diminishing battery power consumption, and constructing a system that exhibits greater integration with emergency services. IoT device battery life improvement and the development of more sophisticated detection algorithms.

3. Research Methods

In conducting research, the data collection method used by the author to formulate the problem is divided into two methods, the first method uses primary methods and the second method uses secondary methods. In data collection using primary methods, the authors surveyed the community

using questionnaires and interviews, and for data collection using secondary methods the authors took data from BPS Bali Province.

3.1 Primary Data Collection

Questionnaire is a data collection technique by providing written questions to respondents to answer. The questionnaire used is a closed questionnaire, namely a questionnaire that has provided answers so that respondents only need to check the column that has been provided [8]. In using this closed questionnaire method, researchers involved the community to fill out the questionnaire.

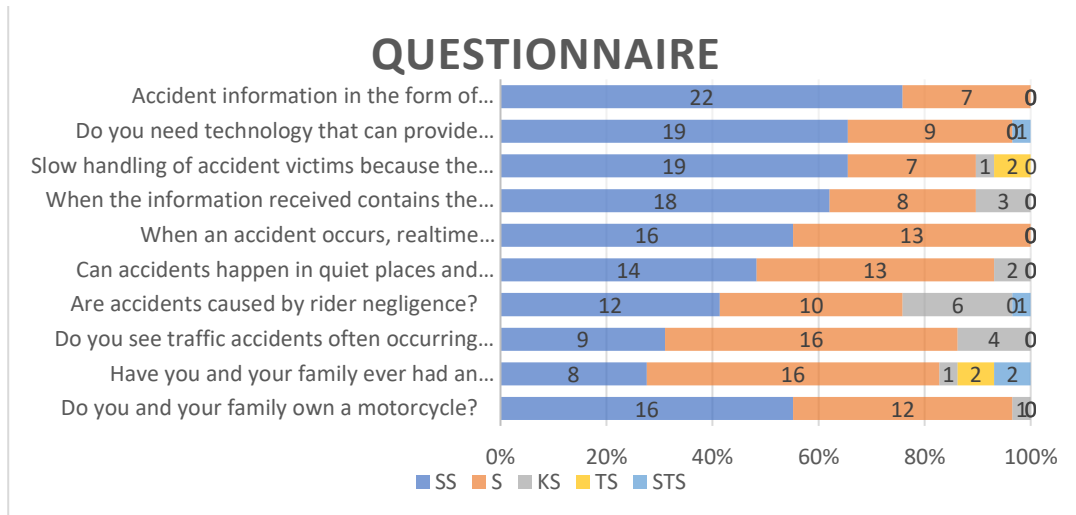


Fig.1. Questionnaire Recapitulation

Based on the recapitulation results that can be seen in Figure 1, it states that almost everyone in the family has a motorcycle and almost all have experienced accidents while riding a motorcycle, and accidents can occur in quiet places and lack of help which results in delays in taking the first action on accident victims. And when an accident occurs real time information and can display coordinates and RPM traveled is something that needs to be applied to motorbikes. It can be concluded from the results of the questionnaire conducted by the researcher that more respondents agreed to the research being carried out.

In the interview method, the author collects data by going directly to the field, conducting questions and answers with respondents who aim to obtain information that can help researchers in achieving research objectives. Interviews conducted with the owner of the rent bike, Mr. I Ketut Supa, located on Jl. Uluwatu I No.39, Jimbaran, Kec. Kuta Sel., Badung Regency, Bali in the interview method can be concluded by the author that the interviewee has difficulty monitoring the motorbikes that are rented out, and when an accident occurs, the interviewee only knows when the tenant reports the incident, resulting in the rent party having difficulty finding motorbikes that have experienced accidents because the tenants of the rent are mostly from outside the area or tourists.

3.2 Secondary Data Collection

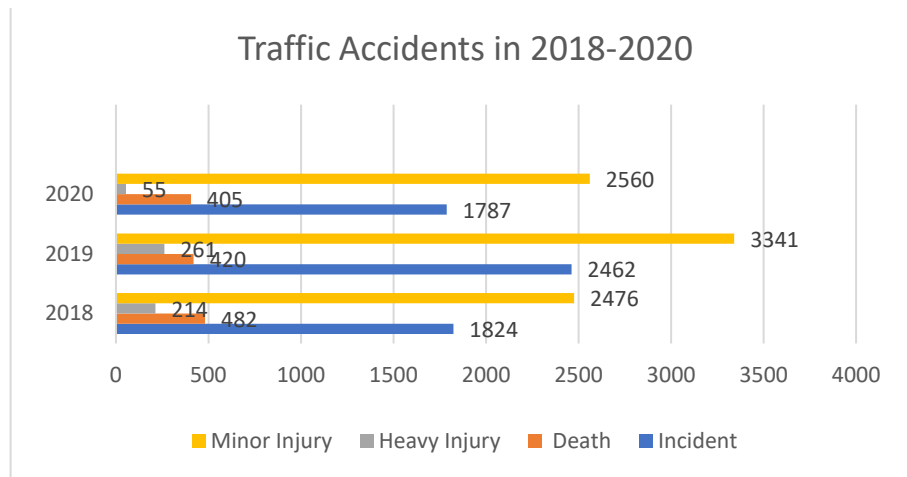


Fig.2. Accident Recapitulation

The Central Bureau of Statistics of Bali Province recorded the number of accidents that occurred from 2018 to 2020 there were thousands of cases and hundreds of victims died on average every year. In 2018 there were 1,824 and 482 victims died, in 2019 there were 2,462 and 420 victims died, in 2020 there were 1,787 cases of accidents which resulted in 405 fatalities (Parthasarathy et al., 2019).

3.3 System Requirements Analysis

System requirements analysis is an understanding of the needs of the new system and developing a system that accommodates these needs. In designing a system, some hardware is needed. Here are some of the hardware needed in this research System requirements analysis is an understanding of the needs of the new system and developing a system that accommodates these needs (Shafique et al., 2020). In designing a system, some hardware is needed. Here are some of the hardware needed in this research

Table 1. Hardware

Tools and Materials Function	Tools and Materials Function
ESP32 As a microcontroller that has WiFi and Bluetooth devices in it.	ESP32 As a microcontroller that has WiFi and Bluetooth devices in it.
Gyroscope sensor as a tilt reader	Gyroscope sensor as a tilt reader
A3144 hall effect as rpm reader	A3144 hall effect as rpm reader
GPS Module as a coordinate point reader	GPS Module as a coordinate point reader
Buck converter as a voltage reducer	Buck converter as a voltage reducer
Jumper cable as a circuit connector	Jumper cable as a circuit connector
Motor battery as a voltage source	Motor battery as a voltage source

In addition to analyzing the hardware requirements above, this system design also requires software. The following are some of the software (software) used can be seen in table 2 below.

Table 2. Software

Software (software) Function	Software (software) Function
Arduino IDE As a controller programmer	Arduino IDE As a controller programmer
Proteus 8 Professional As an electronic circuit schematic designer application	Proteus 8 Professional As an electronic circuit schematic designer application
Sketchup as a 3D design application	Sketchup as a 3D design application
Microsoft Visio As a process flow diagram designer application	Microsoft Visio As a process flow diagram designer application
Telegram As a notification output application	Telegram As a notification output application

Based on table 2, an analysis of the software requirements used in this research can be presented. This software needs analysis aims to identify the specifications and types of software used from the

design stage to implementation. Some of the software used is equipped with their respective functions, which will help in carrying out the research process more efficiently and effectively. For example, software for design will facilitate the creation of accurate and detailed designs, while software for implementation will support proper coding and testing. By choosing software that suits the needs, it is expected that the research process can be carried out in a more structured manner and the results produced can be optimized. Thus, selecting the right software is an important step in the success of research.

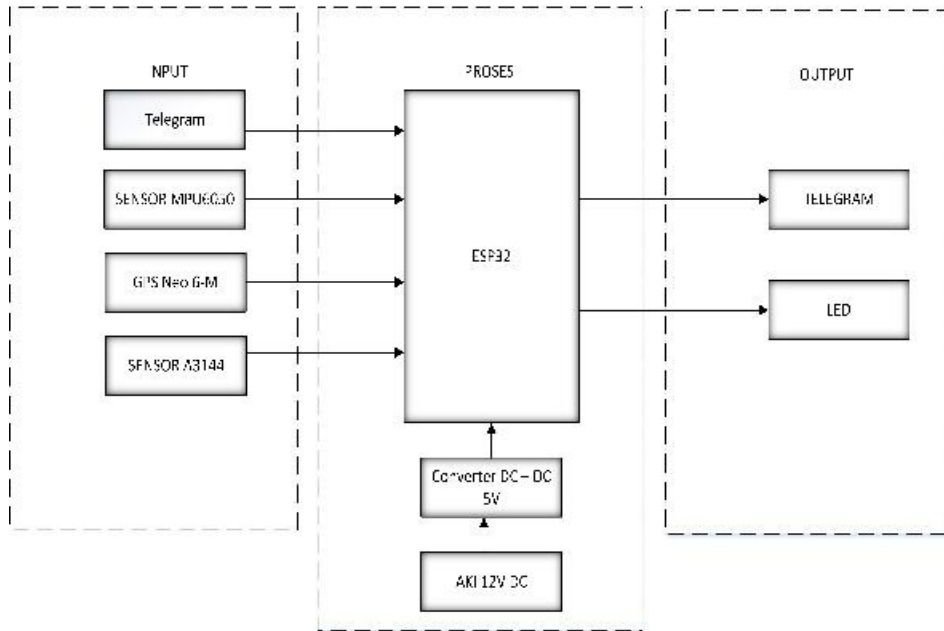


Fig.3. System Block Diagram

The system block diagram of the research design of a telegram notification system for motorcycle accidents based on the internet of things has three block parts that have their respective functions - each can be seen in Figure 3.

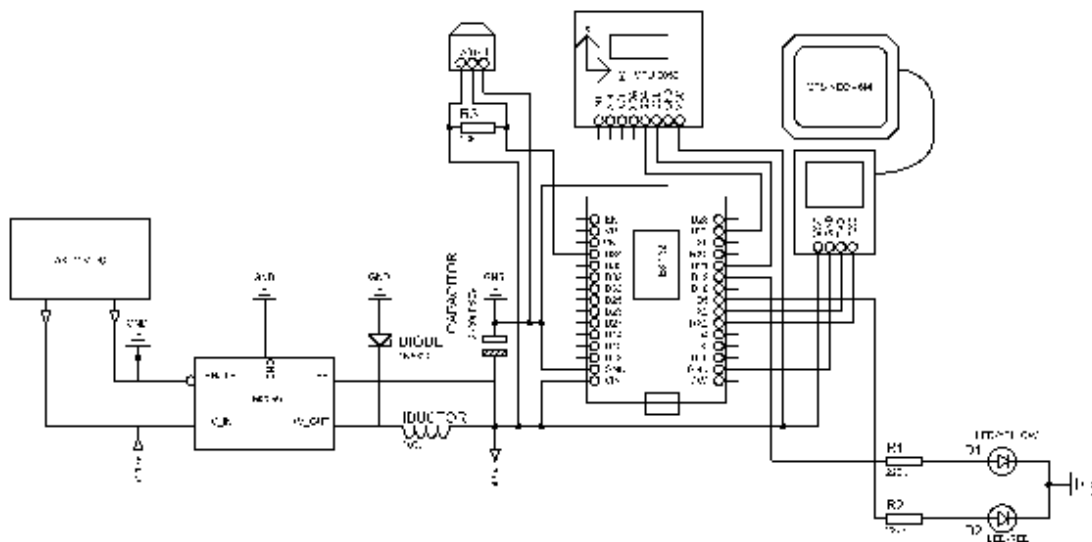


Fig.4. System Schematic

In this internet of things-based telegram notification system for motorcycle accidents, there are several components that are directly connected to the ESP32 microcontroller. Among them are the A3144 sensor, Neo-6m GPS sensor, and MPU6050 gyroscope sensor and converter. The system uses voltage from a motorcycle battery which is reduced from 12V dc to 5V dc. The entire wiring pattern can be seen in Figure 4.

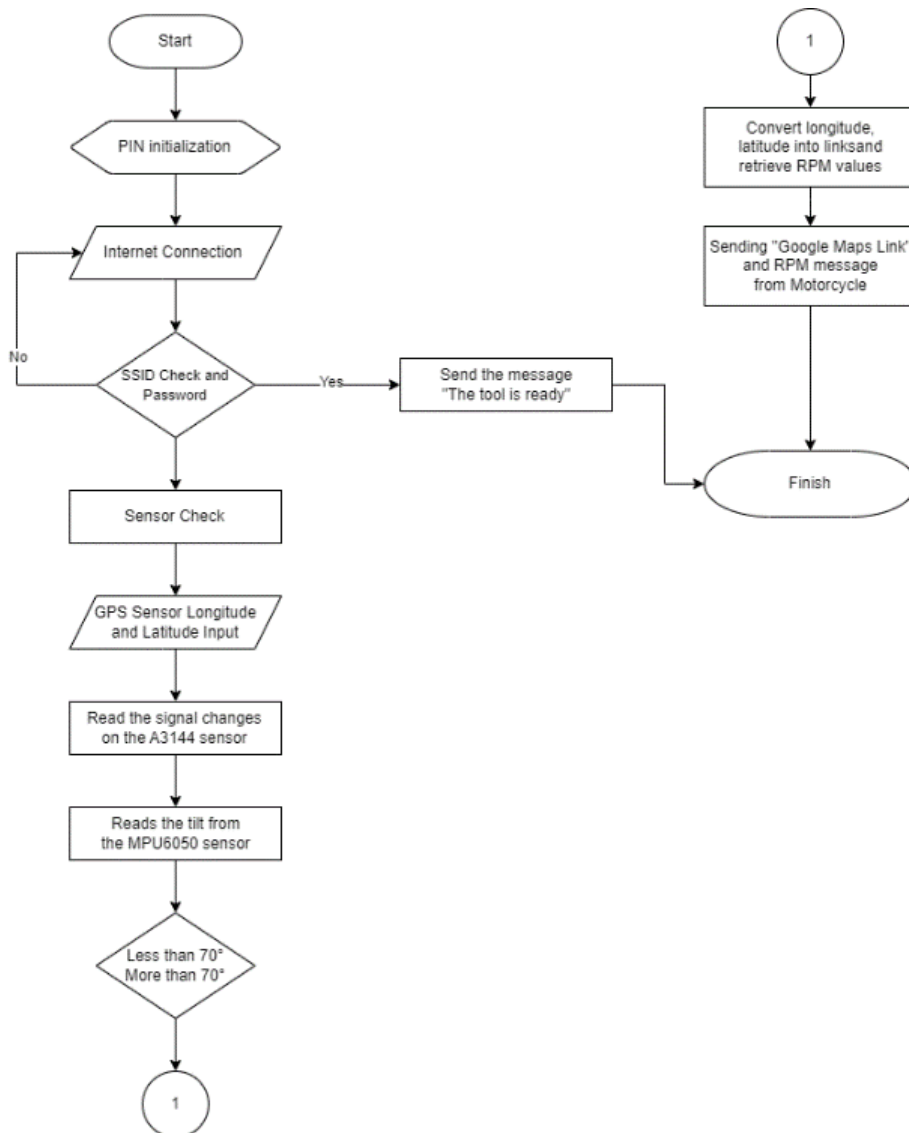


Fig.5. System Flowchart

In figure 5 Flowchart display illustrates how this system can work to send accident message notifications via telegram containing RPM (revolutions per minute) and coordinates when the driver has an accident, in the form of a link.

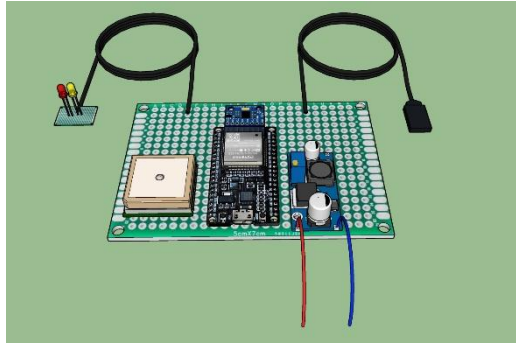


Fig.6. Tools Design

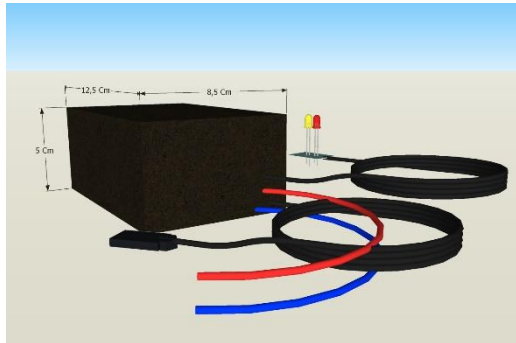


Fig.7. Overall Design

In the design of the telegram notification system tool for motorcycle accidents, researchers use an X4 type box that is widely available on the market. to keep the tool from liquid and debut. This tool has an overall height of 5 cm and a base area of 8.5 cm x 12.5 cm in which there is an ESP32 microcontroller, MPU 6050 sensor module, GPS sensor module, and red and yellow leds, which can be seen in Figure 6 and Figure 7.

4. Results and Discussions

4.1 Data Description

Testing on this system is carried out by dividing it into each component, from testing the MPU6050 tilt sensor, reading the coordinate point on the GPS sensor and reading the PRM on the A3144 sensor.

Table 3. Sensor Testing MPU6050

Number	Sensor MPU	Clinometer	Condition	
			Dropped	Not Dropped
1	Y : -1.09	0.1 ⁰		✓
2	Y : 18.16	17.2 ⁰		✓
3	Y : 29.66	28.7 ⁰		✓
4	Y : -29.30	28.4 ⁰		✓
5	Y : 71.23	70.4 ⁰	✓	
6	Y : -71.51	70.6 ⁰	✓	
7	Y : 51.57	50.7 ⁰		✓
8	Y : 66.28	65.3 ⁰		✓
9	Y : -66.40	65.6 ⁰		✓
10	Y : -51.40	50.5 ⁰		✓

Table 3 shows the results of the mpu 6050 sensor comparison with the clinometer. In this test, the value of the comparison tested is the degree of tilt resulting from the comparison of the sensor and clinometer. The results obtained from the comparison carried out are approximately 0.97% or 1 degree. For a slope of 0 to 690 the motorcycle position does not fall, if it is more than 690 then the motorcycle position falls.

Table 4. Sensor Testing GPS Neo-6M

Number	GPS NEO-6M	Google Maps
1	-8.528166,115.232582	-8.528156,115.232597
2	-8.532435,115.225578	-8.532426,115.225563
3	-8.538120,115.223663	-8.538130,115.223648
4	-8.541471,115.223022	-8.541471,115.223030
5	-8.547791,115.221840	-8.547785,115.221931

Table 4 shows the results of the latitude and longitude comparison obtained by comparing the NEO-6M GPS sensor with google maps, where the comparison measured in this test process is the coordinates obtained from the NEO-6M GPS sensor and google maps, the average value obtained from 5 tests is 1m and the sensor successfully reads the coordinates properly.

Table 5. Average difference of comparison

Difference	Description	
	Successful	No Success
1 Meter	✓	
1 Meter	✓	
1 Meter	✓	
1 Meter	✓	
1 Meter	✓	
	1 Meter	

Table 6. Sensor Testing A3144

Number	Tachometer	A3144	Difference RPM
1	336	347	11
2	406	409	2
3	414	443	19
4	432	440	8
5	1074	1097	23
6	1057	1079	22
7	1329	1358	29
8	1263	1262	1
9	1324	1350	26
10	1056	1072	16
Average difference of comparison			15,7

Table 6 shows the results of the A3144 sensor comparison with the standard tachometer. In this test the value of the comparison tested is the unit of rotation per minute resulting from the comparison of the sensor and tachometer. The results obtained from the comparison carried out 10 times with a good reading category, the average value of the comparison is approximately 15.6 turns per minute with a percentage value of 98%.

Table 7. Percentage Equation

Percentage Equation	Description	
	Successful	Unsuccessful
97%	✓	
99%	✓	
93%	✓	
98%	✓	
98%	✓	

98%	✓
98%	✓
100%	✓
98%	✓
99%	✓

Table 8. Testing Bot Telegram

Number	Condition	Message Description		Description	
		As per	No	As per	No
1	"/Info"	✓		✓	
2	> 70 ⁰	✓		✓	
3	< 70 ⁰		✓	✓	
4	Error		✓	✓	
5	Error		✓	✓	
6	< -70 ⁰	✓		✓	
7	> -70 ⁰		✓	✓	
8	"/Info"	✓		✓	
9	Error		✓	✓	

Table 7 and table 8 shows the results of sending messages from telegram bots to users. In table 7 testing was carried out 10 times in order to get optimal results, at the testing stage the results obtained, the bot successfully sent the message in accordance with the expected conditions.

5. Conclusion

Contains statements to answer the problems described in the introduction as well as suggestions for further research if needed in accordance with the results of the study is 1) In assembling a system, researchers collect data using questionnaire and interview methods, as a reference for building how the system works, so that the system can work according to what is needed by sources and the community. In the system testing stage from each component tested to overall testing, the system can work as the researcher wants and the system is designed based on data obtained from respondents and the community. 2) At the testing stage all components can function properly as expected. The system is able to send message notifications via telegram when the motorcycle falls with a slope position of less than 700 to more than -700, and the system does not send notifications when the motorcycle slope position is less than 690 to -690. And in testing the GPS sensor can send coordinates quite well, the difference in the comparison distance between the Neo -6M GPS sensor and the researcher's google smartphone is on average 1 meter and the system can read the RPM quite well with an average difference of 15.7 revolutions per minute. In the design of the telegram notification system for motorcycle accidents based on the internet of things that has been implemented, there are several shortcomings, so to make this tool better there are several suggestions that can be implemented, namely: A) In order for the A3144 sensor to be resistant to dust and water, it is necessary to add a more optimal protector with dust-proof materials and does not reduce the magnetic field readings from the sensor. B) For maximum GPS reading results, it is necessary to add a better antenna so that coordinate readings can be more accurate.

References

- Adhiwibowo, W., Daru, A. F., & Hirzan, A. M. (2020). Temperature and Humidity Monitoring Using DHT22 Sensor and Cayenne API. *Jurnal Transformatika*. <https://doi.org/10.26623/transformatika.v17i2.1820>
- Aji Saputra, B., Prasetyo Hidayat, E., Zuhri Arfianto, A., Studi Teknik Kelistrikan Kapal, P., Perkapalan Negeri Surabaya, P., & Studi Teknik Otomasi, P. (2020). Internet of Things-Based

- Steam Pump Motor Protection Due to Voltage Unbalance. *Journal of Robotics and Control (JRC)*, 1(2), 64–69. <https://doi.org/10.18196/JRC.1214>
- Alim, M. E., Ahmad, S., Dorabati, M. N., & Hassoun, I. (2020). Design & Implementation of IoT Based Smart Helmet for Road Accident Detection. *2020 11th IEEE Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON)*, 576–581. <https://doi.org/10.1109/IEMCON51383.2020.9284820>
- Alsaedi, A., Moustafa, N., Tari, Z., Mahmood, A., & Adna N Anwar. (2020). TON-IoT telemetry dataset: A new generation dataset of IoT and IIoT for data-driven intrusion detection systems. *IEEE Access*, 8, 165130–165150. <https://doi.org/10.1109/ACCESS.2020.3022862>
- BenSaleh, M. S., Saida, R., Kacem, Y. H., & Abid, M. (2020). Wireless sensor network design methodologies: A survey. *Journal of Sensors*, 2020, 1–13. <https://doi.org/10.1155/2020/9592836>
- Chamim, A. N. N., Hardyanto, D. C., & Putra, K. T. (2021). Web-Based Flood Hazard Monitoring. *Journal of Robotics and Control (JRC)*, 2(5), 373–379. <https://doi.org/10.18196/JRC.25110>
- Desnanjaya, I. G. M. N., & Arsana, I. N. A. (2021). Home security monitoring system with IoT-based Raspberry Pi. *Indonesian Journal of Electrical Engineering and Computer Science*, 22(3), 1295. <https://doi.org/10.11591/ijeecs.v22.i3.pp1295-1302>
- Desnanjaya, I. G. M. N., & Made Aditya Nugraha, I. (2022). Design and Build Body Temperature Detection and Personal Identity Recognition Through E-ID Card and Photo Based on IoT. *ISESD 2022 - 2022 International Symposium on Electronics and Smart Devices, Proceeding*, 9–13. <https://doi.org/10.1109/ISESD56103.2022.9980725>
- Desnanjaya, I. G. M. N., Nugraha, I. M. A., Sarasvananda, I. B. G., & Iswara, I. B. A. I. (2021). Portable Waste Based Capacity Detection System Using Android Based Arduino. *Proceedings of 2nd 2021 International Conference on Smart Cities, Automation and Intelligent Computing Systems, ICON-SONICS 2021*, 45–51. <https://doi.org/10.1109/ICON-SONICS53103.2021.9617000>
- Desnanjaya, I. G. M. N., Sudipa, I. G. I., & Pranata, I. W. D. (2020). Performance Analysis Of Balinese Kulkul Beats Information System Based on Website and Android Using ISO 9126. *Proceeding of the Electrical Engineering Computer Science and Informatics*. <https://doi.org/10.11591/eecsi.v7.2035>
- Furizal, F., Sunardi, S., & Yudhana, A. (2023). Temperature and Humidity Control System with Air Conditioner Based on Fuzzy Logic and Internet of Things. *Journal of Robotics and Control (JRC)*, 4(3), 308–322. <https://doi.org/10.18196/jrc.v4i3.18327>
- Goyal, S. B., Bedi, P., Kumar, J., & Ankita. (2022). Realtime accident detection and alarm generation system over IoT. *Multimedia Technologies in the Internet of Things Environment, Volume 2*, 105–126. https://doi.org/10.1007/978-981-16-3828-2_6
- Husni, M., Ginardi, R. V. H., Gozali, K., Rahman, R., Indrawanti, A. S., & Senoaji, M. I. (2021). Mobile Security Vehicle's based on Internet of Things. *Journal of Robotics and Control (JRC)*, 2(6), 546–551. <https://doi.org/10.18196/JRC.26135>
- Jauhari, M. F., Abdurahman, D., & Triono, Y. (2021). Motorbikes Automatic Module for Hand Brake and Fuel Cut Off Relay. *2nd Borobudur International Symposium on Science and Technology (BIS-STE 2020)*, 302–305. <https://doi.org/10.2991/aer.k.210810.052>
- Kumar, N., Acharya, D., & Lohani, D. (2020). An IoT-based vehicle accident detection and classification system using sensor fusion. *IEEE Internet of Things Journal*, 8(2), 869–880. <https://doi.org/10.1109/JIOT.2020.3008896>
- Lin, K., Li, Y., Sun, J., Zhou, D., & Zhang, Q. (2020). Multi-sensor fusion for body sensor network in medical human-robot interaction scenario. *Information Fusion*, 57, 15–26. <https://doi.org/10.1016/j.inffus.2019.11.001>
- Najmurokhman, A., Kusnandar, Daelami, A., Nurlina, E., Komarudin, U., & Ridhatama, H. (2020). Development of Temperature and Humidity Control System in Internet-of-Things based Oyster Mushroom Cultivation. *2020 3rd International Seminar on Research of Information Technology and Intelligent Systems, ISRITI 2020*. <https://doi.org/10.1109/ISRITI51436.2020.9315426>

- Nasir, M. Z. M., Salimin, S., Chan, B., & Jumaat, S. A. (2020). Prototype development of smart parking system powered by solar photovoltaic. *Indonesian Journal of Electrical Engineering and Computer Science*, 18(3), 1229–1235. <https://doi.org/10.11591/ijeecs.v18.i3.pp1229-1235>
- Nugraha, I. M. A., Desnanjaya, I. G. M. N., Pranata, I. W. D., & Harianto, W. (2021). Stability Data Xbee S2b Zigbee Communication on Arduino Based Sumo Robot. *Journal of Robotics and Control (JRC)*. <https://doi.org/10.18196/jrc.2370>
- Parthasarathy, S., Arun, T., Hariharan, S., & Lakshmanan, D. (2019). Smart irrigation system. *International Journal of Innovative Technology and Exploring Engineering*, 8(8). <https://doi.org/10.2139/ssrn.3462943>
- Pravalika, V., & Rajendra Prasad, C. (2019). Internet of things based home monitoring and device control using Esp32. *International Journal of Recent Technology and Engineering*. <https://doi.org/10.35940/ijrte.2277-3878>
- Rehman, S. U., Khan, S. A., Arif, A., & Khan, U. S. (2021). IoT-based accident detection and emergency alert system for motorbikes. *2021 International Conference on Artificial Intelligence and Mechatronics Systems (AIMS)*, 1–5. <https://doi.org/10.1109/AIMS52415.2021.9466055>
- Shafique, K., Khawaja, B. A., Sabir, F., Qazi, S., & Mustaqim, M. (2020). Internet of things (IoT) for next-generation smart systems: A review of current challenges, future trends and prospects for emerging 5G-IoT Scenarios. *IEEE Access*, 8, 23022–23040. <https://doi.org/10.1109/ACCESS.2020.2970118>
- Shubham, S. P., Kumar, M., & Jain, S. (2021). A survey on iot based automatic road accident detection. *2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS)*, 1–7. <https://doi.org/10.1109/ICICCS51141.2021.9432159>
- Sudipa, I. G. I., Sarasvananda, I. B. G., Prayitno, H., Putra, I. N. T. A., Darmawan, R., & WP, D. A. (2023). *Teknik Visualisasi Data*. PT. Sonpedia Publishing Indonesia.
- Taştan, M., & Gökozan, H. (2019). Real-time monitoring of indoor air quality with internet of things-based e-nose. *Applied Sciences (Switzerland)*. <https://doi.org/10.3390/app9163435>
- Thornton, M. A. (2021). Arduino III: Internet of Things. *Synthesis Lectures on Digital Circuits and Systems*, 16(1), 1–237. <https://doi.org/10.2200/S01077ED1V03Y202102DCS060>