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# Forest Fire Monitoring using Integrated Microcontroller-Based Drones

**Khafilah Ainur Rasyidin [1], Rini Puji Astutik [2]**
[1,2.] Universitas Muhammadiyah Gresik,
[1] Email : khafilahainurrasyidin@gmail.com

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**ABSTRACT:** Forest fires are catastrophic events that pose serious threats to ecosystems, biodiversity, and human health. Conventional monitoring techniques are often limited in coverage and response time, making early detection difficult and ineffective. This study proposes the development of an advanced forest fire monitoring system utilizing unmanned aerial vehicles (drones) equipped with integrated microcontroller-based technology. The system consists of a master microcontroller installed on the drone and a slave microcontroller connected to various environmental sensors, including temperature, humidity, hazardous gas detection, and flame sensors. Sensor data is transmitted in real-time to a web server, enabling remote visualization and monitoring of potential fire occurrences. The research focuses on the design, integration, and implementation of the monitoring system, as well as the development of a user-friendly web interface for real-time data presentation. The expected outcomes of this study include improved accuracy in forest fire detection, enhanced data availability for environmental analysis, reduced operational costs, and a more responsive forest monitoring framework. This system is anticipated to serve as a reliable and scalable solution for early warning and disaster mitigation in forest fire management.

**KEYWORDS:** Forest Fire, Drone, Temperature Sensor, Smoke Sensor, Humidity Sensor, Fire Sensor.

## I. INTRODUCTION

Forest fires are one of the natural disasters that have a significant impact on the environment and human health. Forest fires that occur repeatedly will disrupt the balance of ecosystems that should be stable [1]. The impact of forest fires is not only detrimental to the environment, but also to humans. The causes of forest fires mostly come from natural factors, such as the dry season, lightning strikes, and climate change [2]. It is important to control forest fires effectively. To ensure that forest fires can be extinguished quickly, early identification is crucial. However, conventional monitoring methods such as the use of satellites and watchtowers face various constraints, including limited detection and coverage [3].

Drones for environmental monitoring have become an innovative and practical solution as technology advances. Drones have the ability to reach locations that are difficult to access, provide a wide view, and enable real-time monitoring. However, to improve monitoring efficiency, integration of advanced sensor and data communication technologies is required [4]. In a previous study entitled "Design of Forest Fire Detection System Based on Mcu Esp8266 Node" has paved the way for the development of innovative forest fire monitoring technology. By using the Mcu Esp8266 Node, the study successfully produced a system capable of detecting forest fires efficiently and transmitting information in real-time. This technology integration proves that a microcontroller-based approach can be an effective solution in environmental monitoring [5]. Another research entitled "Forest Fire Monitoring System Based on Internet of Things (IoT)" has shown that the use of IoT technology in monitoring forest fires can increase the effectiveness of early detection and rapid response to fire incidents. In this study, environmental sensors were connected via a wireless network to collect real-time temperature, humidity, and smoke data, which were then analyzed and displayed on a web-based platform [6]. Therefore, the authors propose the use of integrated microcontroller-based drones to monitor forest fires. Parameters such as temperature, humidity, presence of harmful gases, and presence of fire will be incorporated into this system to detect forest fires. The system uses one master microcontroller placed on the drone and two slave microcontrollers placed at the observation site equipped with sensors. This research aims to develop a forest fire monitoring system using an integrated microcontroller-based drone. With this system, it is expected to increase the efficiency and effectiveness of early detection of forest fires, so as to reduce the damage caused. This research is significant because it can contribute to environmental conservation efforts and mitigation of forest fire disasters in the future.

## II. OVERVIEW

### A. DRONE X3 PRO

A drone, or Unmanned Aerial Vehicle (UAV), is an aircraft that is operated without a human pilot on board. Drones can be remotely controlled or fly autonomously using software and GPS [7]. Initially, this advanced technology was only used by the military. However, over time, its use has expanded and been adopted by various sectors. Government agencies utilize drones to connect intelligence with land, while the general public now also has access to using drones for various daily purposes [8].

### B. ESP32

ESP32 is a 2.4 GHz WiFi and Bluetooth combo chip designed with TSMC 40 nm ultra low-power technology. This technology is designed to achieve the best power performance, demonstrating robustness, versatility, and reliability in a wide range of applications. This makes the ESP32 an ideal choice for IoT projects that require wireless connectivity and efficient power management [9].

### C. Arduino Uno

Arduino Uno is an electronic development board that is very popular among DIY (Do It Yourself) and prototyping enthusiasts. The board uses an ATmega328 microcontroller and is programmed using the Arduino-based programming language. The Arduino Uno is equipped with various input/output (I/O) pins that can be used to connect sensors and other devices [10]. The combination of ease of use, flexibility, and broad support makes the Arduino Uno an ideal choice for developing electronics projects [11].

### D. DHT11

The DHT11 sensor is a temperature and humidity sensor that is often used in various electronics projects, including forest fire monitoring systems. This sensor can measure temperature in the range of -20°C to 50°C with a resolution of 1°C, and air humidity in the range of 20% to 90% with a resolution of 1%. The DHT11 uses digital technology, making it easy to integrate with microcontrollers such as the Arduino Uno [12]. However, it has limitations in temperature and humidity measurement range, as well as lower resolution compared to more expensive sensors. Nonetheless, the DHT11 remains a popular choice due to its simplicity and ability to fulfill basic temperature and humidity measurement needs [13].

### E. MQ-2

The MQ2 sensor is a gas sensor used to detect the concentration of harmful gases in the air, such as LPG gas, smoke, alcohol, carbon monoxide (CO), and methane. This sensor works on the principle of electrical resistance changes that occur when exposed to certain gases. The MQ2 has two legs that are used to provide power and read the output signal [14].

### F. Flame Sensor

Flame sensor is a device used to detect the presence of fire or flame by detecting the spectrum of light produced by fire, usually in the ultraviolet (UV) or infrared (IR) range. This sensor works by detecting light in that specific spectrum range and sending an electrical signal as an indication of the presence of fire [15]. In this research, flame sensors are used on drones to detect the presence of fire in the forest, enabling early detection of forest fires. The advantages of using flame sensors include fast response, high accuracy in distinguishing between fire and other light sources, and portability that makes it easy to install on mobile devices such as drones [16].

### G. LoRa

LoRa SX1278 is one of the wireless transceiver modules based on LoRa (Long Range) technology. LoRa itself stands for "Long Range," which refers to a wireless module technology designed to transmit data over long distances with low power consumption. The LoRa SX1278 module was developed by the Semtech company [17]. The module is ideal for use in battery-based applications, enabling long battery life. With the combination of wide range, power efficiency, and high penetration capability, LoRa SX1278 becomes an excellent choice for various IoT applications that require long-distance communication [18].

### H. WEB Server

A web server is hardware or software that provides services to store, manage, and access web pages, data, or applications over the internet [19]. Its function is to receive requests from clients, which are usually web browsers, and send back the requested web pages or requested data to the client via secure HTTP (Hypertext Transfer Protocol) or HTTPS (Hypertext Transfer Protocol Secure) protocol [20].

## III. Method

This research method begins with a literature study taken from scientific journals, books, and other reliable sources to support this research. Direct sources are obtained from the results of discussions and consultations with lecturers or people who have competence in this field. The literature studied are, Drone, Microcontroller, DHT11 Sensor, MQ-2 Sensor, Flame sensor, LoRa SX1278 Communication Module.

### A. System Block Concept

First, the drone acts as the main platform equipped with an ESP32, which acts as the brain of the system. The ESP32 plays an important role in retrieving data with LoRa from the Arduino Uno which acts to control the sensors, such as temperature, humidity, hazardous gas presence, and fire presence sensors, and manages the collection of data from these sensors. These sensors are key components in the system, as they are responsible for collecting the data required for forest fire monitoring. The temperature sensor is used to detect suspicious changes in temperature and humidity, the hazardous gas sensor is used to detect the presence of hazardous gases that signal a fire, while the fire sensor detects the presence of flames if a fire has already occurred. Next, the ESP32 will transfer the data that has been collected by the drone to the web server device. The data that has been received by the web server will be displayed in the form of a web that has been specifically designed to monitor real-time forest fire monitoring data. Through this web server, users can easily monitor forest fire conditions and take the necessary steps according to the information provided. Thus, the interaction between the drone, ESP32, Arduino Uno, LoRa, and web server forms an efficient and effective system for forest fire monitoring.

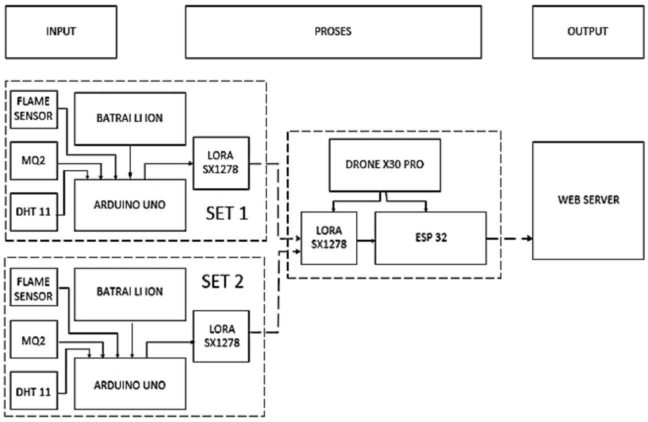


Fig 1. Concept Block Diagram of the System

### B. RESEARCH HARDWARE DESIGN

This hardware design is made to use the components that will be used for the hardware layout.

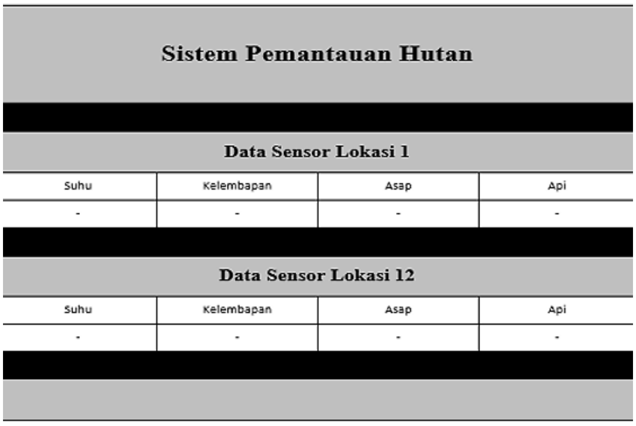


Fig 3. Software Design

Hardware placement is designed in such a way as to have an optimal layout.

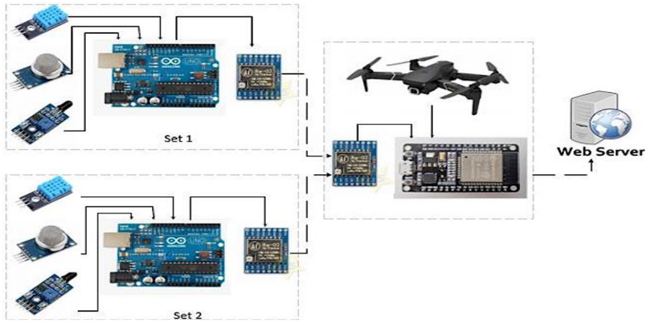


Fig 2. Research Hardware Design

### C. SOFTWARE DESIGN

The software design for the forest fire monitoring system includes several components that work together to control the hardware, collect and process data, and displaying real-time information to users via a web server. The firmware on the ESP32 and Arduino Uno microcontrollers is responsible for controlling the sensors, collecting data, and managing data communication. The ESP32 has a key role in controlling communication with the LoRa module, receiving data from the Arduino Uno, processing the data, and sending it to the web server via Wi-Fi. Meanwhile, the Arduino Uno is in charge of controlling the temperature sensor (DHT11) and hazardous gas sensor (MQ2), collecting data, and sending it to ESP32 via LoRa.

### D. SYSTEM WORK PROCESS

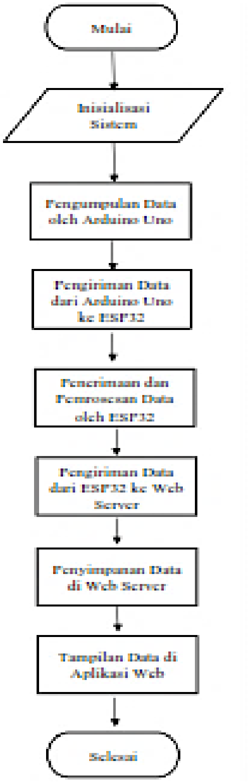


Fig 4. System Flowchart

**Description:**

1. System Initialization: The system is initialized, including hardware (drone, ESP32, Arduino Uno, sensors, LoRa module) and software (web server, database).
2. Data Collection by Arduino Uno: The Arduino Uno activates and reads data from the temperature, humidity, hazardous gas presence, and fire presence sensors periodically.
3. Data Transmission from Arduino Uno to ESP32: Sensor data is transmitted from Arduino Uno to ESP32 using LoRa module.
4. Data Receiving and Processing by ESP32: The ESP32 receives data from the Arduino Uno, processes it, and prepares the data to be sent to the web server.
5. Data Transmission from ESP32 to Web Server: The data that has been processed by the ESP32 is sent to the web server via a Wi-Fi connection.
6. Data Storage on Web Server: The web server receives data from the ESP32 and stores it in a database for further analysis.
7. Data Display in the Web Application: The web application retrieves data from the web server and displays it in real-time to the user in the form of graphs, tables, and interactive maps, and provides notifications if suspicious conditions are detected.

### E. DATA TRANSMISSION PROCESS USING LORA E32

Arduino Uno is used as the slave microcontroller in this system, where each Arduino Uno is equipped with DHT11 sensors to measure temperature and humidity, MQ2 to detect gas, and Flame Sensor to detect fire. These two Arduino Uno, referred to as Slave 1 and Slave 2, are responsible for collecting data from these sensors. The collected data is then sent to the master microcontroller, the ESP32, using the LoRa E32 communication module. LoRa (Long Range) is a wireless communication technology that enables long-distance data transmission with low power consumption. This technology is very suitable for IoT (Internet of Things) applications that require long-distance communication. The LoRa E32 module on each Arduino Uno is set to communicate with the LoRa E32 module connected to the ESP32. Data transmission is carried out in a predetermined format so that ESP32 can recognize and process data properly. Each Arduino Uno sends sensor data periodically via LoRa E32 to the ESP32, ensuring that data from each monitoring location is received by the master microcontroller.

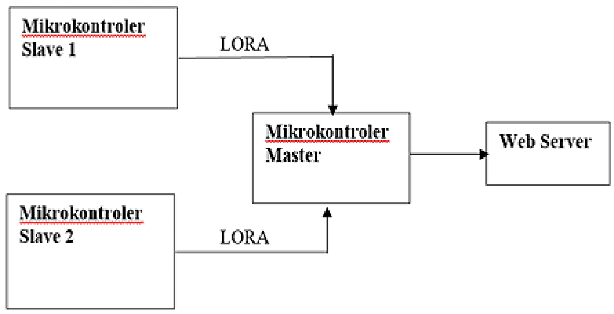


Fig 5. Data Transmission Process

After the ESP32 receives data from both Arduino Uno through the LoRa E32 module, the data is processed or accumulated as needed. The next step is to send the processed data to the web server using the HTTP protocol. The ESP32 is connected to a Wi-Fi network to access the internet and transmit this data.

## IV. RESULTS AND DISCUSSION

The results and analysis of the tests will include the suitability of the tool parameters used as well as the evaluation of the controls in the forest area. Furthermore, the data obtained will be further analyzed. The tests carried out include the Flame Sensor test, MQ-2 Sensor test, DHT11 Sensor test, and LoRa method test. There are also pictures of the tools used during the research, the picture can be seen as follows. In the following data collection design, several measurements of each sensor at the location will be displayed. This test will include the success of sending data via LoRa and the suitability of measurement values between the web server and the data taken at the location.

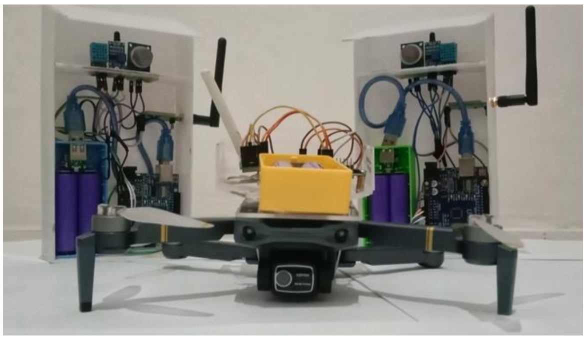

Fig 6. Research tools

### A. TESTING SET 1

Testing on set 1 will be done to take the following data:

Tests on set 1 were carried out on December 11-12, 2024 with various parameters measured, including air humidity (%), temperature (°C), smoke concentration (PPM), and detection of the presence of fire (High/Low) test results High then the fire is not detected. Data was sent via LoRa and successfully received by the web server for each test. On December 11, 2024, the measurement results showed that the air humidity was in the range of 75.44% to 81.00%, the temperature ranged from 29.14°C to 34.57°C, and the smoke concentration increased from 1.50 PPM at 09:20 to 5.22 PPM at 13:20. Sensors detected fire throughout the test with a status of High. On December 12, 2024, humidity was recorded between 73.43% and 80.12%, with temperatures ranging from 30.10°C to 32.50°C. Smoke concentration increased from 2.37 PPM at 10:13 am to 7.86 PPM at 2:13 pm, indicating an increase in air pollution levels. The presence of fire remained detected in all measurements with a status of High. All data was successfully transmitted using LoRa and received on the web server, indicating that the communication system is stable and reliable for environmental monitoring.

Tbl 1. Test Results on Set 1

| NO | Date, Time | Place Set 1 | | | | Lora Delivery | Web Server | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Hum (%) | Temp (C°) | Smk (PPM) | Fire (H/L) | (Yes/No) | Hum (%) | Temp (C°) | Smk (PPM) | Fire (H/L) |
| 1 | 11/12/2024 09.20 | 81.00 | 29.14 | 01.50 | High | Yes | 81.00 | 29.14 | 01.50 | High |
| 2 | 11/12/2024 11.20 | 79.20 | 30.00 | 03.19 | High | Yes | 79.20 | 30.00 | 03.19 | High |
| 3 | 11/12/2024 13.20 | 75.44 | 34.57 | 05.22 | High | Yes | 75.44 | 34.57 | 05.22 | High |
| 4 | 12/12/2024 10.13 | 80.12 | 30.10 | 02.37 | High | Yes | 80.12 | 30.10 | 02.37 | High |
| 5 | 12/12/2024 12.13 | 77.32 | 32.50 | 05.52 | High | Yes | 77.32 | 32.50 | 05.52 | High |
| 6 | 12/12/2024 14.13 | 73.43 | 31.28 | 07.86 | High | Yes | 73.43 | 31.28 | 07.86 | High |

### B. TESTING ON SET 2

Testing on set 2 will be done to take the following data:

Tbl 2. Test Results on Set 2

| NO | Date, Time | Place Set 1 | Lora Delivery | Web Server |
|---|---|---|---|---|

| | | Hum (%) | Temp (C°) | Smk (PPM) | Fire (H/L) | (Yes/No) | Hum (%) | Temp (C°) | Smk (PPM) | Fire (H/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13/12/2024 08.33 | 81.70 | 30.19 | 01.84 | High | Yes | 81.70 | 30.19 | 01.84 | High |
| 2 | 13/12/2024 10.33 | 70.11 | 32.08 | 04.05 | High | Yes | 70.11 | 32.08 | 04.05 | High |
| 3 | 13/12/2024 12.33 | 70.50 | 35.02 | 08.39 | High | Yes | 70.50 | 35.02 | 08.39 | High |
| 4 | 15/12/2024 09.15 | 83.21 | 31.52 | 02.57 | High | Yes | 83.21 | 31.52 | 02.57 | High |
| 5 | 15/12/2024 11.15 | 78.32 | 34.71 | 04.69 | High | Yes | 78.32 | 34.71 | 04.69 | High |
| 6 | 15/12/2024 13.15 | 80.44 | 33.89 | 06.92 | High | Yes | 80.44 | 33.89 | 06.92 | High |

Test set 2 was conducted on December 13 and 15, 2024, with measured parameters including air humidity (%), air temperature (°C), smoke concentration (PPM), and fire detection (High/Low). All data was successfully sent via LoRa and received by the web server without a hitch. On December 13, 2024, the measurement results recorded that: At 08:33, the humidity was 81.70%, the temperature was 30.19°C, and the smoke concentration was 1.84 PPM, At 10:33, the humidity dropped to 70.11%, the temperature increased to 32.08°C, and the smoke concentration increased to 4.05 PPM, At 12:33, the temperature continued to rise to 35.02°C, the humidity increased slightly to 70.50%, and the smoke concentration reached 8.39 PPM, and the sensor detected the presence of fire with High status throughout the test. On December 15, 2024, the measurement results showed that: At 09:15, the humidity reached 83.21%, the temperature 31.52°C, and the smoke concentration 2.57 PPM, At 11:15, the humidity dropped to 78.32%, the temperature increased to 34.71°C, and the smoke concentration rose to 4.69 PPM, At 13:15, the temperature slightly decreased to 33.89°C, while the humidity rose to 80.44%, with the smoke concentration reaching 6.92 PPM, and The presence of fire remained detected throughout the test with a status of High then the fire was not detected. These test results confirm that the LoRa-based monitoring system operates well and is able to transmit data to the web server accurately, supporting optimal environmental monitoring.

## V. CONCLUSION

Based on tests conducted on December 11-12, 2024 (Set 1) and December 13-15, 2024 (Set 2), the LoRa-based monitoring system is proven to operate properly and is able to transmit data to the web server smoothly without problems. The measurement results showed that the air humidity was in the range of 70.11% to 83.21%, the temperature ranged from 29.14°C to 35.02°C, and the smoke concentration increased gradually with the highest value reaching 8.39 PPM. The sensor detected a High status on the presence of fire throughout the test, indicating that no fire was detected during the monitoring. Overall, the system performed stably and accurately, making it an effective tool for monitoring the forest environment, especially in measuring humidity, temperature, and air pollution levels due to smoke.

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## REFERENCE

[1] S. N. Koplitz et al., "Public health impacts of the severe haze in Equatorial Asia in September-October 2015: Demonstration of a new framework for informing fire management strategies to

reduce downwind smoke exposure," Environ. Res. Lett., vol. 11, no. 9, 2016, doi: 10.1088/1748-9326/11/9/094023.

[2] A. Ruldivem, U. A. Ahmad, and R. E. Saputra, "Design And Implementation Of Forest Fire Detection System Using Lora (Long Range) Communication," e-Proceeding Eng., vol. 9, no. 3, pp. 1024-1039, 2022.

[3] R. E. Wibowo, R. Teguh, and A. Lestari, "Early Detection of Forest and Ground Fires Utilizing Exif Extraction on Image Information Based Image Processing," J. Technol. Inf. J. Science and Appl. Bid. Tech. Inform., vol. 15, no. 1, pp. 1-12, 2021, doi: 10.47111/jti.v15i1.1934.

[4] N. Padang, "INNOVATION IN USING DRONE IN MONITORING PLANT GROWTH AND MONITORING PEST," Student Project. Faculty. Pertan., vol. 1, no. 1, 2024.

[5] I. G. A. Ari Kukuh Sentanu, I. G. A. K. Diafari Djuni, and N. Pramaita, "Design of a Forest Fire Detection System Based on Node Mcu Esp8266," J. SPEKTRUM, vol. 8, no. 1, p. 286, 2021, doi: 10.24843/spektrum.2021.v08.i01.p32.

[6] J. Pebralia, R. Raaiqa Bintana, and I. Amri, "Forest Fire Monitoring System Based on Internet of Things (IoT)," Commun. Fis. Indoensia, vol. 19, no. 3, pp. 183-189, 2022, doi: 10.31258/jkfi.19.3.183-189.

[7] F. P. Hirsan, A. Kurniawan, R. Ridha, and A. Yuniarman, "The DANGER OF DRONE USE IN THE KKOP AREA NEAR THE AVIATION OPERATION SAFETY AREA (KKOP) is a manned area that has the potential to reach the most remote areas worked by the community (Darmayanti, 2023). The government must," vol. 7, no. 3, pp. 1-6, 2023.

[8] F. Gunawan, "Natural Gas Leak Detection System Via Telephone Call and SIM 800L Module," pp. 6-51, 2019, [Online]. Available: https://eprints.akakom.ac.id/8485/

[9] M. N. Nizam, Haris Yuana, and Zunita Wulansari, "Esp 32 Microcontroller as a Web-Based Door Monitoring Tool," JATI (Journal of Mhs. Tech. Inform., vol. 6, no. 2, pp. 767-772, 2022, doi: 10.36040/jati.v6i2.5713.

[10] S. Samsugi, Z. Mardiyansyah, and A. Nurkholis, "Automatic Irrigation Control System Using Arduino Uno Microcontroller," J. Technol. and Sist. Embedded, vol. 1, no. 1, p. 17, 2020, doi: 10.33365/jtst.v1i1.719.

[11] MA. PAHLEVI, "Battery Characteristics," Politek. Negeri Sriwij., vol. I, pp. 1-9, 2013.

[12] D. Srivastava, A. Kesarwani, and S. Dubey, "Measurement of Temperature and Humidity by using Arduino Tool and DHT11," Int. Res. J. Eng. Technol., vol. 5, no. 12, pp. 876-878, 2018, [Online]. Available: www.irjet.net

[13] S. Hadi, R. P. M. D. Labib, and P. D. Widayaka, "Comparison of Measurement Accuracy of LM35 Sensor and DHT11 Sensor for Internet of Things Based Temperature Monitoring," STRING (Unit of Writing Ris. and Inov. Technol., vol. 6, no. 3, p. 269, 2022, doi: 10.30998/string.v6i3.11534.

[14] R. C. Pandey, M. Verma, and L. K. Sahu, "Internet of Things (IOT) Based Gas Leakage Monitoring and Alerting System with MQ-2 Sensor," Int. J. Eng. Dev. Res., vol. 5, no. 2, pp. 2321-9939, 2017.

[15] B. Rahman, F. Pernando, and N. Indriawan, "Gas and Fire Leakage Monitoring System Using MQ-2 Sensor and Flame Sensor Based on Android," J. Sensi, vol. 8, no. 2, pp. 209-222, 2022, doi: 10.33050/sensi.v8i2.2429.

[16] A. Hartono and A. Widjaja, "Fire Detection Prototype Using Flame Sensor, Dht11 Sensor and Nodemcu Esp8266 Microcontroller Based on Website," Semin. National. Mhs. Fak. Technol. Inf. Jakarta-Indonesia, no. September, pp. 734-741, 2022.

[17] Y. Apriani, W. A. Oktaviani, and I. M. Sofian, "Vessel Tracking System Based on LoRa SX1278," J. Ilm. Tech. Electrocomput. and Inform., vol. 9, no. 3, pp. 693-707, 2023, doi: 10.26555/jiteki.v9i3.26385.

[18] M. Liandana, "Application of LoRa Technology to an Initial Wearable Device Prototype," Res. Comput. Inf. Syst. Technol. Manag., vol. 2, no. 2, p. 40, 2019, doi: 10.25273/research.v2i02.5191.

[19] A. U. Rahayu, I. Taufiqurrahman, and N. R. Mutiarasari, "Smart irrigation system with fuzzy logic on sunflower plants based on Internet of Things," Journal of Energy and Electrical Engineering, vol. 6, no. 1, 2024.

[20] R. D. Prakoso and Asmunin, "Implementation and Performance Comparison of Proxmox in Virtualization with Three Virtual Servers," J. Manaj. Inform., vol. 8, no. 1, pp. 79-86, 2018, [Online]. Available: https://ejournal.unesa.ac.id/index.php/jurnal-manajemen-informatika/article/view/22864