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Design and Development of a Mini Weather Station Based on Wemos D1 with Real-Time Monitoring Using Laptop or Smartphone

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Abstract

The need for real-time weather data is crucial in the maritime industry. Utilizing Weather Station technology ensures the required accuracy in navigation systems and supports educational purposes, particularly for research needs. Weather forecasting involves collecting climate data from specific maritime regions quantitatively. Monitoring weather conditions is vital in the maritime sector due to the unpredictable nature of sea weather. Therefore, it is essential to develop cost-effective, accurate, efficient, and well-integrated weather measurement technologies for onboard navigation systems. The proposed prototype utilizes a Wemos D1 microcontroller equipped with various sensors, including temperature, rainfall, wind speed, and humidity sensors. These sensors collect data that the microcontroller processes, which can then be monitored on a Personal Computer (PC) or smartphone. This data aims to provide valuable insights for seafarers and passengers, enabling them to anticipate sea conditions to ensure safety and comfort during voyages. The study was conducted through literature reviews, exploring the design and construction of a weather station system and referencing previous research documentation. It included identifying material requirements, preparing tools and components, and developing software and hardware configurations to enable an efficient weather monitoring device. Experiments were conducted on individual sensors, including the DHT22, BMP180, anemometer, and rain sensor. Hardware development involved integrating these sensors with a Wemos D1 microcontroller, which was subsequently connected to software capable of real-time monitoring via laptop or smartphone.Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text ever since the 1500s.

Keywords: Arduino, Mini Weather Station, Weather Sensors, SolarCell User Interface, Wemos D1.

1. Introduction

Adverse weather conditions pose a significant threat to the maritime industry, often resulting in shipwrecks, collisions, and other accidents that lead to the loss of lives and property. These incidents are particularly prevalent in Indonesia, where maritime transport accidents such as ship sinkings and vehicle instability caused by strong winds and waves are frequent (Qudratullah et al., 2017; Desnanjaya & Iswara, 2018; Sudarman et al., 2021; Mahendra et al., 2020). Addressing this issue requires effective monitoring and prediction of weather conditions.

Extreme weather phenomena, including unexpected wind direction changes and anomalies in weather patterns, have become increasingly common. These irregularities disrupt normal seasonal cycles, turning periods expected to be calm into hazardous ones. This unpredictability makes real-time weather monitoring along shipping routes essential to ensure maritime safety (Sudarman et al., 2021; Qudratullah et al., 2017; Mahendra et al., 2020; Prasetyo et al., 2022).

Conventional weather monitoring methods rely on sensors fixed at specific locations, with data collection performed manually. This approach is inefficient, especially for remote or hard-to-reach areas. To address this limitation, Mini Weather Stations equipped with advanced sensors and real-time data transmission capabilities are now used to monitor weather conditions effectively across various locations (Ananta et al., 2023; Desnanjaya & Iswara, 2018; Qudratullah et al., 2017; Sudarman et al., 2021).

Weather measurement tools are critical to providing precise and timely data for navigation and safety. Key parameters such as rainfall, air temperature, humidity, wind speed, and atmospheric pressure must be processed with high accuracy. This data supports decision-making processes in navigation and weather forecasting (Mahendra et al., 2020; Sudarman et al., 2021; Desnanjaya & Iswara, 2018; Sari et al., 2020).

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Automatic Weather Stations (AWS) have been developed in Indonesia for many years to automate weather monitoring. However, their high cost limits their implementation in remote or underserved areas. Advances in microcontroller technology have paved the way for cost-effective AWS systems that enable broader deployment and increased accessibility (Qudratullah et al., 2017; Prasetyo et al., 2022; Mahendra et al., 2020; Ananta et al., 2023).

Microcontrollers are compact, integrated circuits that function as small computers. With programmable inputs, outputs, processors, and memory, they are ideal for real-time operations, making them an essential component of AWS systems. These versatile devices offer a cost-effective solution for automating weather data collection and processing (Desnanjaya & Iswara, 2018; Qudratullah et al., 2017; Prasetyo et al., 2022; Ananta et al., 2023).

Due to their broad functionality, microcontrollers are often referred to as "computers on a chip." They are specifically designed to perform real-time operations, enabling the efficient collection and monitoring of weather parameters. This advancement has revolutionized maritime safety, providing a reliable and automated solution for predicting and responding to weather conditions (Ananta et al., 2023; Mahendra et al., 2020; Desnanjaya & Iswara, 2018; Sari et al., 2020).

2. Material and methods

2.1. Literature

The process of designing and building a weather station system begins with an in-depth literature search. This step includes examining existing documentation from prior research, which provides a foundation for understanding current advancements and limitations in weather station technology. Additionally, relevant resources such as books, websites, and journals are explored to gather comprehensive insights on the subject (Qudratullah et al., 2017; Sari et al., 2020; Prasetyo et al., 2022).

Existing studies highlight the importance of using various sensors, such as those for temperature, humidity, wind speed, and rainfall, to monitor weather parameters effectively. The integration of these sensors into a centralized system has been a focal point in recent technological developments, especially in creating cost-effective and efficient weather monitoring solutions (Ananta et al., 2023; Desnanjaya & Iswara, 2018; Hidayana et al., 2024).

Furthermore, research emphasizes the role of microcontrollers in enabling automated weather stations. Microcontrollers, such as Wemos D1, have become pivotal due to their low cost, programmability, and ability to process real-time data from multiple sensors. These features make them a suitable choice for developing weather station prototypes aimed at improving maritime safety and navigation (Desnanjaya & Iswara, 2018; Mahendra et al., 2020; Prasetyo et al., 2022).

Exploration of prior studies also uncovers challenges in weather station development, particularly in data transmission and system integration. Addressing these issues requires a multidisciplinary approach that combines hardware design, software development, and system optimization. Resources such as scientific journals and technical reports offer valuable insights into overcoming these challenges and enhancing the reliability of weather station systems (Qudratullah et al., 2017; Sari et al., 2020; Rahman et al., 2023).

Lastly, online platforms and databases play a significant role in supporting literature searches by providing access to the latest studies and technological innovations. These sources complement traditional references such as books and journal articles, ensuring that the research is up-to-date and aligns with global advancements in weather monitoring technology (Prasetyo et al., 2022; Sudarman et al., 2021; Mahendra et al., 2020).

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2.2. Methods

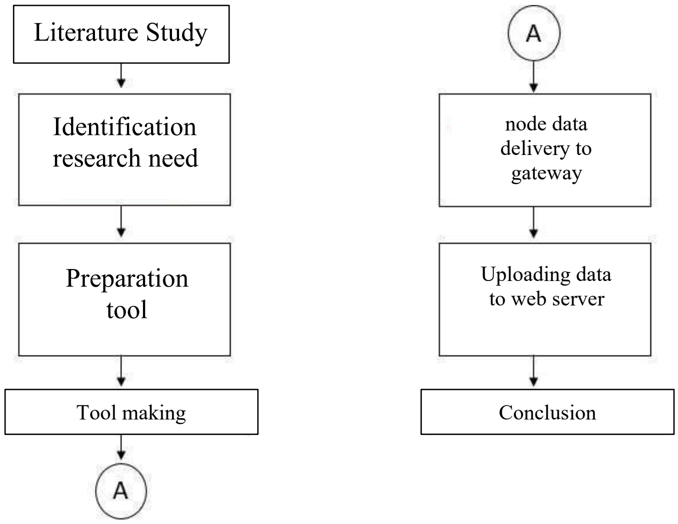

Figure 1. flowchart procedure

The research methodology employed in this study follows an experimental approach, involving several systematic steps. The initial phase includes a comprehensive literature review, where prior research documentation is analyzed. This phase also involves referencing credible sources, such as scientific journals, technical reports, and books, to establish a strong theoretical foundation. Additionally, discussions with academic supervisors provide valuable insights into the existing systems used in weather stations (Prasetyo et al., 2022; Handandi et al., 2023).

The subsequent step focuses on the development of the system program. This involves integrating sensors with the Wemos D1 microcontroller to create a functional weather station. Sensors for parameters such as temperature, humidity, wind speed, and rainfall are configured to ensure accurate data acquisition. This integration process highlights the versatility of Wemos D1 in handling real-time sensor data efficiently (Ananta et al., 2023; Desnanjaya & Iswara, 2018; Mahendra et al., 2020).

The use of Wemos D1 as the microcontroller is central to the system's design due to its programmability and cost-effectiveness. Programming the microcontroller requires aligning sensor functionalities with the system's operational goals, emphasizing simplicity and accuracy. The development process adheres to established guidelines and practices to optimize system performance (Sudarman et al., 2021; Mahendra et al., 2020; Prasetyo et al., 2022).

By combining theoretical studies and practical implementation, the methodology ensures a robust framework for developing the weather station. This dual approach of literature analysis and system prototyping provides a reliable foundation for achieving accurate and cost-effective weather monitoring solutions (Satrianata et al., 2023; Kurniawan et al., 2023).

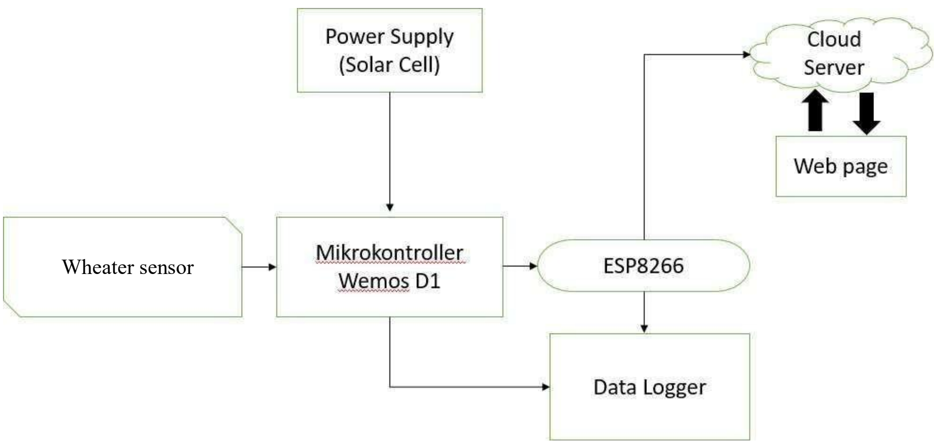

Figure 2. block diagram system

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3. Results and discussion

3.1. Result

After the design and selection of components are completed, the next step is the realization phase, which involves assembling and constructing the circuits that were designed earlier. This stage focuses on translating the theoretical design into a functional system by carefully integrating each component according to the predefined specifications. The assembly process ensures that all components work together efficiently to create a fully operational weather station.

Once the components are successfully assembled, the system is tested to verify the functionality of each part. The wiring and connections are double-checked, and the software is uploaded to the microcontroller for initial trials. This phase aims to ensure that the system performs as expected and is ready for further testing and optimization before deployment in real-world conditions.

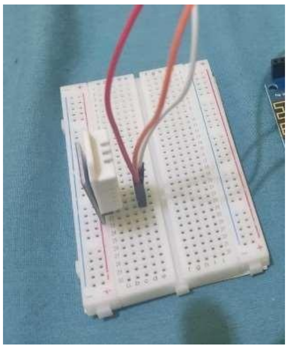

Figure 3. DHT22

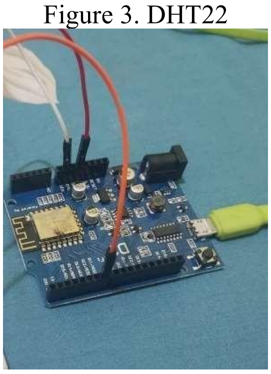

figure 4. Wemos D1

figure 5. Rain sensor

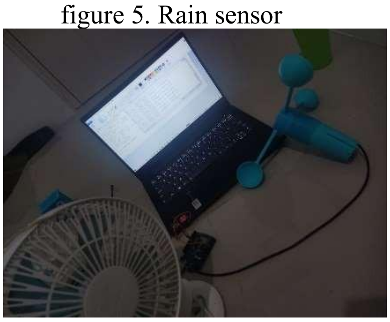

Figure 6, Anemometer sensor

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The mechanical design involves the development of the DHT22 temperature and humidity sensor. The DHT22 sensor has three pins: VCC for power input, GND for ground, and an Output pin, which is connected to the appropriate pins on the Wemos D1 microcontroller. This setup allows the sensor to accurately measure temperature and humidity.

The hardware construction includes the integration of the Wemos D1 microcontroller and the DHT22 sensor circuit. The Wemos D1 functions as the central control unit, managing the connections to various sensors, including the DHT22, BMP180, Rain Gauge, and Anemometer. This configuration enables efficient data collection and processing for the weather station system.

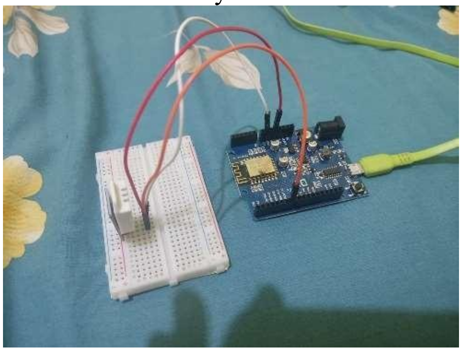

Figure 7. DHT dan Wemos D1

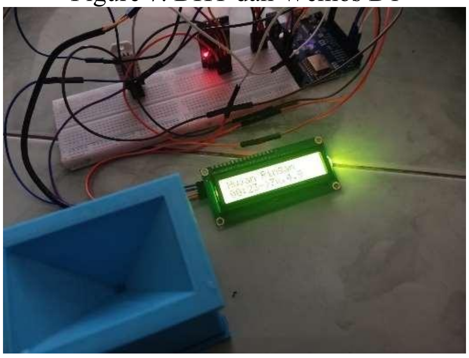

Figure 8. rain sensor & RTC

The development of the system utilizes Arduino IDE for programming. The programming language used for Wemos D1 is very similar to that of Arduino, as Wemos is compatible with Arduino. Therefore, the Wemos board is available within the Arduino IDE, complete with the necessary libraries.

The programming for this system involves integrating inputs from the DHT22 sensor, Rain Gauge, BMP180 sensor, and Anemometer. The testing process includes both hardware testing and system testing. Hardware testing focuses on evaluating the sensor circuits and the Wemos D1 circuit, while system testing ensures that the program runs correctly according to the code uploaded.

Hardware testing includes evaluating the DHT22 sensor and Wemos D1, as well as uploading data to the serial monitor. Below is the table of sensor testing results:

1. DHT22SensorTesting
   a.AirTemperatureandHumidityThe DHT22 sensor was used to measure both air temperature and humidity in a room. After conducting the tests, the following data was obtained.
2. RainSensorTesting(TippingBucket)
   To assess rainfall conditions in the field, the researcher initially tested the Rain Gauge module using water droplets and cotton to simulate rain and check whether the sensor could detect it. After conducting the tests, the data on rainfall conditions were recorded as follows.

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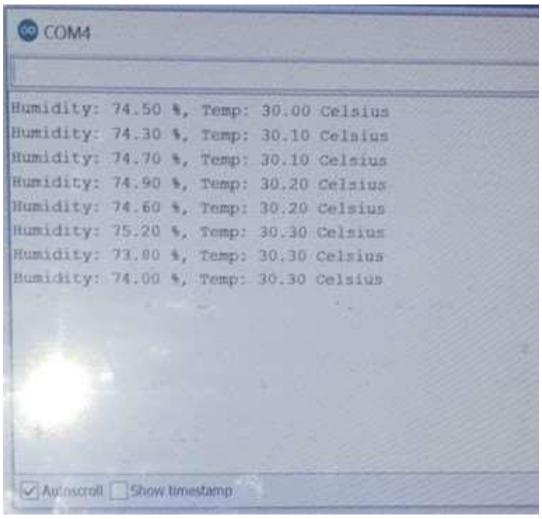

Figure 9. output serial monitor

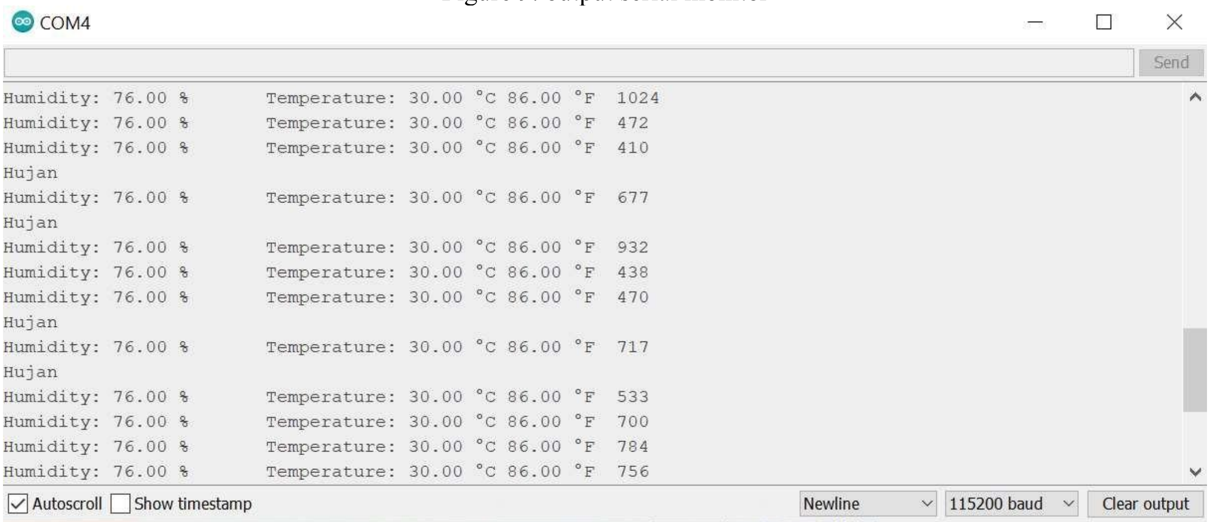

Figure 10. Rain Gauge Sensor test data results (Rainfall)

Software testing includes testing the Arduino IDE program with sensors and testing the Wemos D1 program listing and uploading data to be displayed via the Blynk application. The program that has been created is connected using a micro USB cable and after successfully uploading the program and testing the Wemos D1 program listing, the data output will appear in the Blynk application or website display.

Data collection was carried out in the researcher's house and at Fisherman's Harbor, Taddan Camplong, Madura, East Java. The location selection for this research was carried out based on the amount of weather data that could be taken inside the researcher's room or outside, such as a fishing port that could be reached to be used as a place for the research process and testing of the Miniature Weather Station tool.

In this research the author collected data by placing a Weather Station using power from a battery where the battery is supplied via solar panels which utilize sunlight energy. An example of data collection from the Mini Weather Station tool can be seen in the image below.

3.2. Discussion

After testing the hardware and software, the system is tested by taking data on the sensors. From the test results on this system, the following data results were obtained

:

- Air temperature observation results (DHT22)

  Air temperature observations in the research were carried out in the researcher's room. It can be seen that the graph below has experienced increases and decreases and some of the data results are not stable due to several reasons, including errors in treating the sensor, and the value from zero is deviating. And human activities that cause pollution, such as from vehicles and households, are considered triggers for warming temperatures.

Figure 11. Air temperature data graph (DHT22)

- Humidity observation results

Humidity observations were carried out in the researcher's room. It can be seen that the graph below also experiences the same thing as the DHT22 sensor and some out-of-sync data is produced between the serial monitor and the data on ThingSpeak which is caused by mistreatment of the sensor. And human activities that cause pollution, such as from vehicles and households, are considered triggers for warming temperatures.

Figure 12. Humidity data graph (DHT22)

- Rainfall observation results (Tipping Bucket)

Rainfall observations carried out by researchers were carried out in the researcher's room with a connection using the Internet of Things in a private house. It can be seen in the graphic image below where the graph has decreased because the module was not dripped with water. The existence of data differences that are not constant or even distorted is caused by errors in the treatment of the sensor, and the zero value in the sensor is not appropriate. To carry out rainfall experiments, researchers do this by dripping water on the sensor so they can collect data.

Figure 13. rain fall result

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- Observation Time: Friday, June 17 2022. 09:46
- Funnel (Container) Area: 5.5cm x 3.5cm = 19.2cm2

Table 1. Rainfall observation data results

Type of Rain	**Rainfall (mm)**	**Number of Tipping**	**Time (s)**
Cloudy	0.00	0	0
Light rain	0.50	20	60
Moderate rain	20.00	50	100
Heavy rain	50.00	100	150
Very heavy rain	100.00	150	200
Extreme rain	150.00	160	220

- Anemometer Sensor Testing

To determine wind speed at a location, researchers use an anemometer sensor. After conducting research, data was obtained from the research results for wind speed below.

Table 2. Anemometer data result

time	Wind speed (m/s)	Rotation round(rpm)
08.00	2.14	102.00
08.10	4.27	204.00
08.12	5.96	282.00
08.15	5.91	279.00
08.20	2.26	108.00

4. Conclusion

Based on the research conducted, the following conclusions can be drawn:

1. The Mini Weather Station is capable of accurately measuring various weather parameters, including temperature, air humidity, atmospheric pressure, wind speed, and rainfall. These measurements allow for a comprehensive monitoring of weather conditions, making the system highly useful for applications in both maritime and terrestrial environments.
2. The performance of the Mini Weather Station demonstrates consistent stability, with the system successfully collecting real-time data. This ability to gather up-to-date information allows users to track weather conditions effectively, providing valuable insights into environmental factors that could impact safety and operations.
3. The experimental results from the different sensors sometimes showed slight variations in the data, such as small increases and decreases in readings. These fluctuations can be attributed to various factors, including sensor calibration errors, environmental influences, or potential inaccuracies in sensor placement. While these deviations were minor, they highlight the need for careful sensor management and calibration to ensure the highest level of accuracy in data collection.
4. The integration of various sensors with the Wemos D1 microcontroller has proven to be an effective approach, with each component working in harmony to produce accurate weather measurements. Despite some minor discrepancies, the overall system functioned as expected, confirming the feasibility of using affordable components for weather monitoring.
5. The system's real-time monitoring capability, combined with its ability to transmit data to a PC or smartphone for further analysis, makes the Mini Weather Station a promising tool for both educational and practical applications. However, further research and development may be necessary to improve the sensor's accuracy and address the occasional discrepancies observed during testing.

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