Weather Monitoring and Classification Tools Using Fuzzy Logic Method Based on Internet of Things for Agriculture

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Agriculture is a crucial sector that faces significant challenges due to climate change, such as altered rainfall patterns, increased temperatures, and extreme weather, which threaten productivity. This research aims to design and develop a weather monitoring and classification tool utilizing the Fuzzy Logic method based on the Internet of Things (IoT). The system integrates sensors for temperature, humidity, air pressure, wind speed, and rainfall, processing the data through Fuzzy Logic to classify weather into sunny, cloudy, light rain, moderate rain, and heavy rain. The results are accessible in real-time via an LCD screen and the Blynk application. Achieving 100% accuracy in monitored conditions, the system operates continuously for 24 hours, powered by solar energy. Unlike traditional systems, this tool provides innovative solutions to weather-related agricultural challenges, enabling farmers to make informed decisions and mitigate losses due to extreme weather. This research contributes to advancing IoT applications in precision agriculture, providing a reliable, sustainable, and scalable solution to weather monitoring.

Keywords—Fuzzy Logic, Internet Of Things, Precision Agriculture, Solar Energy, Weather Monitoring

I. INTRODUCTION

The agricultural sector faces growing challenges due to climate change, as evidenced by shifting rainfall patterns, rising temperatures, and extreme weather events. These changes significantly threaten agricultural productivity, requiring innovative approaches to enhance resilience and sustainability in farming. Integrating the Internet of Things (IoT) into agriculture has proven to be a crucial strategy in tackling these issues. IoT applications enable real-time data collection and analysis, equipping farmers with the tools to make informed decisions and mitigate the impacts of climate variability on crop production[1], [2], [3].

Recent research emphasizes the transformative role of IoT in agricultural practices, especially in weather monitoring and management. For example, smart weather stations equipped with sensors allow continuous tracking of environmental factors like temperature, humidity, and rainfall [4], [5]. These systems not only deliver timely data but also enhance the precision of weather forecasts, which is critical for effective farm management. Additionally, the use of fuzzy logic to process this data allows for categorizing weather conditions, thereby enabling farmers to make proactive and well-informed decisions [6].

Despite advancements in IoT-based weather monitoring, there is a gap in integrating fuzzy logic methods to enhance the interpretation of collected data. Conventional systems often rely on binary classifications, which may fail to capture the complexity of weather patterns. This research aims to address this limitation by developing a fuzzy logic-based classification system that divides weather into five categories: sunny, cloudy, light rain, moderate rain, and heavy rain. This approach not only improves weather prediction accuracy but also equips farmers with actionable insights tailored to specific weather conditions[7].

This study's uniqueness lies in its focus on both technological and practical aspects of agricultural weather monitoring. By using solar energy to power the system, the proposed tool ensures sustainable energy use and continuous operation. Real-time weather data is made accessible via an LCD screen and the Blynk application [8]. The integration of renewable energy with IoT technology marks a significant advancement in precision agriculture, offering a scalable solution adaptable to diverse farming environments [9].

Furthermore, the study contributes to IoT applications in agriculture by demonstrating the effectiveness of combining fuzzy logic with real-time monitoring. The findings aim to provide farmers with valuable insights to reduce losses caused by extreme weather events. By addressing the need for more advanced data interpretation methods, this research seeks to strengthen agricultural resilience in the context of climate change [10].

In summary, the proposed weather monitoring and classification tool represents a major advancement in applying IoT technologies to agriculture. By leveraging fuzzy logic for data classification and incorporating renewable energy, this research addresses immediate agricultural challenges while promoting sustainable sector development. The subsequent sections of this paper will detail the methodology, results, and implications of these findings for the future of agricultural practices.

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II. METHODOLOGY

This research consists of several stages which will produce a system that can work properly. The overall research framework process is :

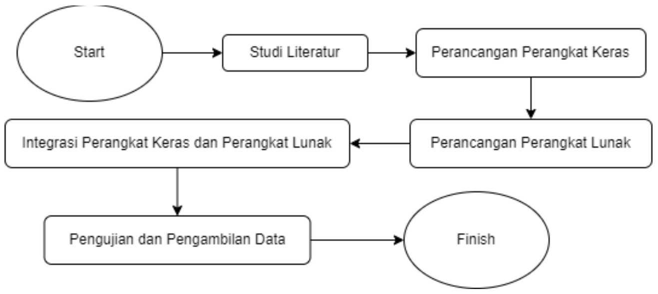

Fig. 1. Research Farmework

A. Literature Study

This study draws from diverse literature to establish the relevance of IoT and fuzzy logic in modern agriculture. Previous works have demonstrated the potential of IoT in real-time environmental monitoring, while fuzzy logic has proven effective in managing uncertainty in agricultural systems. However, few studies have explored the combined application of these technologies in weather classification for agricultural purposes.

B. Hardware Design

Hardware design is the design of the device to be made, the components used must be considered to avoid damage during system testing. These components should have characteristics that are in accordance with the needs of making tools. The hardware design begins with the block diagram in Figure

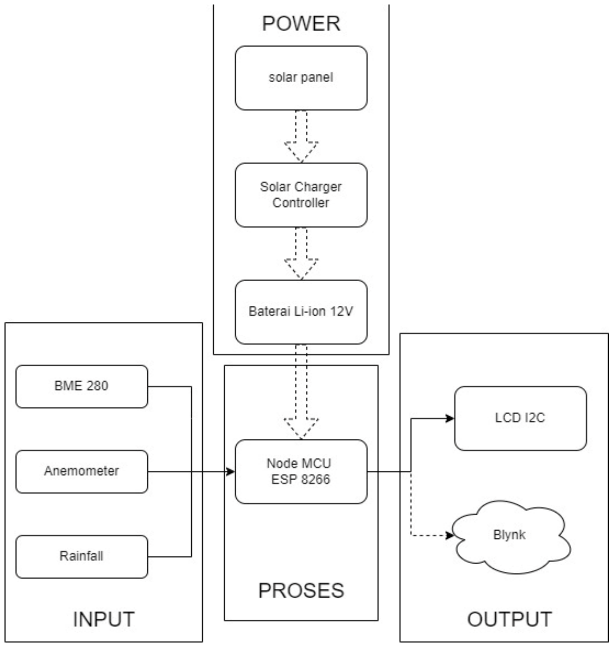

Fig. 2. Hardware Block Diagram

The following is an explanation of the block diagram above:

Solar panels are utilized to harness solar energy and convert it into electricity. The energy generated is regulated and stored in a 12V lithium-ion battery via a solar charge controller, ensuring safe and efficient charging. This battery serves as a stable power source for the system during periods without sunlight, such as nighttime or cloudy conditions. The ESP8266 module, a microcontroller with Wi-Fi capabilities, processes data from various sensors and sends it to the Blynk application for remote monitoring. Additionally, the ESP8266 powers an I2C LCD screen to display weather data locally. Sensors integrated into the system include the BME280 for measuring temperature, humidity, and air pressure, an anemometer for wind speed, and a rainfall sensor for precipitation levels.

C. Software Design

The software for this system is developed using the Arduino IDE to enable monitoring of weather parameters and facilitate weather classification. The Blynk application plays a crucial role by providing a user-friendly interface to display the results of real-time weather monitoring and classification. This combination of hardware and software ensures accurate data collection, processing, and convenient access to weather information both locally and remotely.

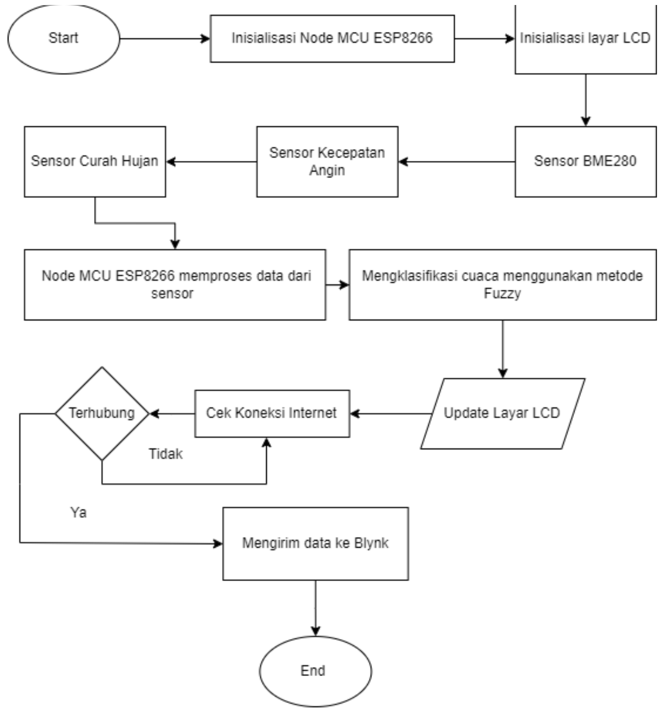

Fig. 3. Software Flowchart

The process begins with system initialization. The Node MCU ESP8266, serving as the microcontroller for data processing and communication between sensor devices, is initialized. Subsequently, the system initializes the LCD screen, which displays weather data. If the LCD screen is not connected, the initialization process will repeat.

Next, the BME280 sensor is activated to measure environmental parameters such as air pressure, temperature, and humidity, which are essential for weather classification.

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Additionally, a wind speed sensor is used to measure wind velocity, providing critical data for more accurate weather classification, particularly for analyzing wind conditions. The rainfall sensor is also checked for its connection, as it measures rainfall intensity. If the sensor is not connected, the system will repeatedly check the connection.

Once data from the BME280 and wind speed sensors are obtained, the Node MCU ESP8266 processes the data. The processed data is then analyzed using the Fuzzy Logic method to classify weather conditions. This method is well-suited for situations involving uncertainty, such as weather classification. The classification results are displayed on the LCD screen, allowing users to view the weather conditions directly.

The system then checks the internet connection of the Node MCU ESP8266. If there is no connection, the process of checking the internet connection will repeat. If connected, the system sends the weather classification data to the Blynk platform. Blynk enables users to monitor weather conditions remotely via a smartphone application or web interface. Finally, the process concludes.

D. Method Development

Fuzzy logic is one of the artificial intelligence methods that can handle uncertain or ambiguous data. In weather measurement systems, fuzzy logic can be used to process sensor data that has high variability such as temperature, humidity, air pressure, wind speed, and rainfall, so as to produce information that is easier to understand such as weather classification which is divided into 5 namely light rain, medium rain, heavy rain, cloudy, and sunny.

1) Design System Fuzzy Logic

TABLE i INPUT AND OUTPUT CLASSIFICATION

Input	**Variabel**	**Output**
Temperature (Suhu)	Dingin, Normal, Panas	Hujan Ringan, Hujan Sedang, Hujan Deras, Mendung, dan Cerah
Humidity (Kelembapan)	Rendah, Sedang, Tinggi	
Pressure (Tekanan)	Rendah, Sedang, Tinggi	
WindSpeed (kecepatan angin)	Pelan, Sedang, Cepat	
Rainfall (Curah hujan)	Tidak Ada, Sedikit, Sedang, Banyak	

2) Sensor variable membership division

TABLE ii TEMPERATURE MEMBERSHIP FUNCTION

Variabel Suhu	**Membership Function**
Dingin	0 – 20º C
Normal	20 – 30º C
Panas	30 – 40º C

TABLE iii HUMIDITY MEMBERSHIP FUNCTION

Variabel Kelembapan	**Membership Function**
Rendah	0 – 40 %
Sedang	40 – 70 %
Tinggi	70 – 100 %

TABLE iv PRESSURE MEMBERSHIP FUNCTION

Variabel Tekanan Udara	**Membership Function**
Rendah	900 – 1010 hPa
Sedang	1010 – 1030 hPa
Tinggi	1030 – 1100 hPa

TABLE v WINSPEED MEMBERSHIP FUNCTION

Variabel Kecepatan Angin	**Membership Function**
Pelan	0 – 5 m/s
Sedang	5 – 8 m/s
Kencang	8 – 30 m/s

TABLE vi RAINFALL MEMBERSHIP FUNCTION

Variabel Curah Hujan	**Memberhsip Function**
Tidak ada	0 mm
Sedikit	0 – 20 mm
Sedang	20 – 50 mm
Banyak	50 – 100 mm

3) Weather classification using fuzzy rules

Fuzzy rules specify how input variables are related to output variables. These rules are expressed in the form “If ... then ...”. Here are some of the rules used:

a) Sunny weather output is determined if Temperature is normal and hot, Humidity is low and moderate, Air Pressure is High, Wind Speed is Slow, and Precipitation is Absent.

b) Cloudy weather output is determined if Temperature is cold, Humidity is high, Air Pressure is medium and low, Wind Speed is medium and Strong, and Precipitation is Absent.

c) Light Rain weather output is determined if Rainfall is slight.

d) Moderate Rain weather output is determined if Rainfall is moderate.

e) Heavy Rain weather output is specified if there is a lot of Rainfall.

Validation was conducted using historical weather data, and the results of the fuzzy classification were compared with official data from national weather agencies to ensure accuracy.

Each sensor was calibrated prior to deployment. The BME280 sensor’s accuracy for temperature, humidity, and air pressure measurements was validated using a laboratory-grade reference device. The anemometer’s wind speed readings were tested against a professional-grade wind tunnel, and the rainfall sensor was validated by simulating different precipitation levels in a controlled environment. The overall system accuracy was found to be within acceptable ranges, achieving a classification

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success rate of 100% during field tests. Field testing was conducted over seven days in an open area. The tool's performance was evaluated under various weather conditions, and data was logged for analysis. The results showed high reliability and consistency, with real-time monitoring and classification outputs aligning with actual weather conditions.

III. Result and Discussions

Weather monitoring and classification system using fuzzy logic method based on IOT is a system that serves to know the weather conditions in realtime that can be seen on the I2C LCD screen and Blynk application. The results of the design are divided into two parts, namely the design of the hardware circuit design, then the results of the software design.

A. Hardware Design Result

The hardware design for this fuzzy logic-based weather measurement tool consists of several main components that work together to collect and process weather data. This system uses solar panels as the main energy source that converts solar energy into electrical energy with a specification of 20 WP. The electrical energy generated is then regulated by the Solar Charger Controller. This module serves to charge the 18650 battery efficiently, using a linear charging method with a maximum current of 30 A. The energy stored in the 18650 12V battery (with a capacity of 12800mAh) is used to provide power for the entire system. The ESP8266 microcontroller acts as the center of data processing and communication in this system. The ESP8266 is in charge of collecting data from various sensors and sending the data to the Blynk platform via WiFi connection. The sensors used include a BME280 sensor that measures temperature, humidity, and air pressure, an anemometer to measure wind speed, and a rainfall sensor that measures rainfall intensity. The data collected by the ESP8266 is processed using the fuzzy logic method to produce an output that represents the weather comfort level. The processed data is then displayed on an I2C LCD, making it easy to monitor weather conditions locally.

Fig. 4. Hardware Design Result

In Figure 4, it can be seen that the monitoring device circuit uses a 170 cm high pole to support each sensor - sensor, solar panel, and controller box. The selection of poles with a height of 170 cm is because the anemometer sensor and solar panel must be in a high place so as not to be obstructed by objects and shadows that can cause the monitoring tool to not work optimally.

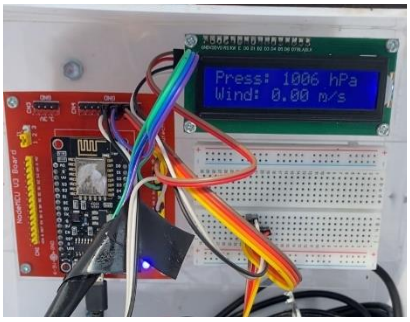

Fig. 5. Device circuit inside the box

In Figure 5, the controller cover box with size P(20cm) x L(20cm) x T(15cm) is used to cover and protect the nodeMCU module, I2C LCD, and protoboard from rain.

B. Software Suite Results

The results of the software suite are displayed on the Blynk application. The following table shows the detection results of several sensors and weather classification.

Fig. 6. View on the Blynk app

From Figure 6, it can be seen that the Weather Station device displays the results of sensor readings - sensors sent data by

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NodeMCU in the form of gauges and graphs. Monitoring using the Blynk application can function properly

C. Tool Testing Results

The testing process of the Internet Of Things (IOT) based weather monitoring and classification tool was carried out at Jalan Kelapa Gading Blok II-A in an open area. Testing was carried out for 7 consecutive days from June 10 - June 16, 2024. In testing this tool there are 3 sensors, namely the BME280 sensor (temperature, humidity, and air pressure), Anemometer sensor (Wind Speed), and Rainfall sensor (rainfall) which are used fuzzy methods to classify weather. The results of the monitoring tool testing carried out can be seen in the following table.

TABLE vii TOOL TESTING RESULTS

Date	*Temperature* (°C)	*Humidity* (%)	*Pressure* (hPa)	*Windspeed* (m/s)	*Rainfall* (mm/mnt)	Cuaca	Cuaca Sebenarnya
10/06/2024	29,04	72,6	1009,76	0,24	0	Cerah	Cerah
	Normal	Tinggi	Rendah	Pelan	Tidak ada		
11/06/2024	33,67	76,28	1010,15	0,17	0	Cerah	Cerah
	Panas	Tinggi	Sedang	Pelan	Tidak ada		
12/06/2024	33,4	75,24	1010,15	0,16	0	Cerah	Cerah
	Panas	Tinggi	Sedang	Pelan	Tidak ada		
13/06/2024	33,67	75,82	1010,15	0	0	Cerah	Cerah
	Panas	Tinggi	Sedang	Pelan	Tidak ada		
14/06/2024	32,34	75,59	1010,38	0,15	0	Cerah	Cerah
	Panas	Tinggi	Sedang	Pelan	Tidak ada		
15/06/2024	32,13	80	1010,15	1,53	0	Cerah	Cerah
	Panas	Tinggi	Sedang	Pelan	Tidak ada		
16/06/2024	31,82	76,28	1010,15	0,52	0	Cerah	Cerah
	Panas	Tinggi	Sedang	Pelan	Tidak ada		

From table , it can be seen that the monitoring tool testing was carried out from Sunday to Saturday. During the 7 consecutive days of testing, the reading results of the weather monitoring tool on Sunday received an accuracy of 100% because the weather and sensor readings from Monday - Sunday were in accordance with data from BMKG. So it can be stated that the accuracy of the monitoring tool reaches 100%, which means that the monitoring tool can function properly.

D. Analysis of Monitoring tool Test Results

The test results of the Internet of Things (IoT)-based weather monitoring tool using the Fuzzy Logic method have shown satisfactory performance during the 7-day test period from June 10 to June 16, 2024. Here are some analysis points from the test results:

Sensor Performance and Reading Accuracy: This tool uses three main sensors: BME280 for temperature, humidity, and air pressure, Anemometer for wind speed, and Rainfall sensor for rainfall. These sensors were able to provide consistent and accurate weather data throughout the test period. From the comparison results between the tool data and the actual weather recorded, the accuracy of the monitoring tool reached 100%, which shows that this tool can function properly and accurately.

Use of the Fuzzy Logic Method: The application of the Fuzzy Logic method in weather classification has proven to be effective. Fuzzy Logic is able to handle the variability of sensor data and produce weather classifications that are close to actual conditions. The test results show that this tool can classify the weather into sunny, cloudy, and rainy well.

Energy Efficiency: The monitoring device uses solar panels as the main power source and batteries as energy storage. Tests were conducted for 7 days non-stop in an open area, and the device continued to operate well even when the solar panel did not get the maximum energy from the sun, such as at night or in cloudy weather. This shows that the power management system works efficiently, ensuring continuity of operation.

This tool requires a connection to the internet so that the sensor reading data can be sent to the blynk server, but when taking data in the middle of the farm still requires an internet connection via Hotspot tethering from a cellphone so that it cannot be left behind because the distance from the farm to the residence is far while the range of cellphone hotspots is usually around 10 meters. Sometimes also the signal in the middle of the farm is very bad so it takes longer for the tool to send the readings to the Blynk server.

Use of Blynk App and LCD: Weather data can be monitored in real-time through the Blynk app and I2C LCD display. The display on the Blynk app shows sensor readings in gauge and graph form, which makes it easy for users to monitor weather conditions. The LCD display also clearly shows temperature, humidity, air pressure, wind speed, and rainfall data.

Testing and Environmental Conditions: Tests were conducted in an open area, ensuring that the tool can operate in varied environmental conditions. The test conditions were continuous for 7 days from June 10 to June 16, proving the durability and reliability of the device in various weather conditions.

IV. CONCLUSION

Based on the research and testing that has been carried out on weather monitoring and classification tools using the Fuzzy Logic method based on Internet Of Things (IOT), it can be concluded that:

The design of weather monitoring and classification tool using fuzzy logic method based on Internet of Things uses several sensors, namely BME 280 sensor that reads temperature, humidity, and air pressure, wind speed sensor, and rainfall sensor. The sensor reading data is processed by the MCU Node and then displayed on the LCD screen and Blynk application.

The application of the fuzzy logic method to the output of each sensor can be done to classify the weather so that it can help agriculture in determining the rice planting schedule in order to increase production.

Integration between monitoring results on the tool and weather classification using fuzzy logic method is done in Arduino IDE software using C++ programming language so that the accuracy reaches 100%. This tool can also be monitored remotely using the Blynk application.

Because this tool requires a connection to the internet so that

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the sensor reading data can be sent to the blynk server, it is necessary to use Long Range (LoRa) communication that can send data remotely without using the internet. It can also use the internet network that is currently booming, namely starlink, because starlink uses satellite internet so that the internet can run smoothly if the tool is placed in the middle of a large farm.

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