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IoT-Based Automatic Clothesline System Using ESP8266 with Fuzzy Logic Control and Web-Based Monitoring

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Abstract

The efficiency and safety of manual clothes drying are significantly affected by weather conditions, such as rainfall, humidity, and limited sunlight. To address these challenges, this study presents the design and implementation of an Internet of Things (IoT)-based automatic clothesline system that uses an ESP8266 microcontroller with fuzzy logic control. The system incorporates multiple environmental parameters, including temperature, humidity, light intensity, and rain detection, to enable adaptive movement of the clothesline and fan activation. A fuzzy inference mechanism handles sensor data uncertainty and generates appropriate control actions in real time. Additionally, a web-based monitoring interface enables users to remotely monitor environmental conditions and system status and to manually control the system. Experimental results show that the system responds effectively to dynamic weather changes, reducing the risk of clothes being exposed to rain and enhancing overall drying efficiency. These findings suggest that the proposed approach offers a practical and reliable solution for smart household automation applications.

A. Introduction

Natural sun-based drying remains widely practiced in Indonesia; however, unpredictable weather conditions, such as sudden rainfall and fluctuating sunlight intensity, often disrupt the drying process. These conditions may cause clothes to become wet again, remain damp, or develop unpleasant odors, thereby affecting daily activities and overall comfort [1]. Recent advancements in the Internet of Things (IoT) offer promising solutions to address these challenges through intelligent automation. IoT enables devices to operate autonomously based on real-time environmental data [2]. In clothes-drying applications, this technology supports automatic systems that detect sunlight intensity, humidity, and rainfall and respond appropriately without direct user intervention, while still allowing remote monitoring [3]. To enhance decision-making accuracy under uncertain environmental conditions, the Fuzzy Logic method is employed.

This study presents an Arduino-based automatic clothes-drying system equipped with a DHT11 sensor, a rain sensor, and an LDR to measure temperature, rainfall, and light intensity. The collected data are processed using Fuzzy Logic to control a protective cover and a DC fan. Furthermore, the system integrates a web-based interface for real-time monitoring. The proposed system aims to improve household efficiency and prevent common issues such as rewetting, dampness, and odor formation in clothes [4].

B. Research Method

This research comprises several stages: literature review, system planning, system testing, analysis, and conclusions. The following are the stages of this research:

1. Literature Review

A literature review has been conducted by examining relevant journals and books. Some of the literature reviewed focuses on automatic clothes-drying systems using IoT devices, specifically implementations with ESP8266 and additional sensors, as well as methods for providing status information via web interfaces. These studies employ moisture, rain, and light sensors to monitor drying conditions, and systems that transmit real-time drying status to a website for user access. The issues addressed in this research and the potential solutions proposed by previous researchers were identified from this preliminary review. Several related studies have been carried out previously.

In 2024 Mastiyanto et.al, developed an Arduino Uno–based automatic clothes-drying system using light, rain, and humidity sensors. The prototype testing results demonstrate its ability to accurately respond to changes in environmental and weather conditions: the rain sensor triggers the roof to close immediately when raindrops or rainfall are detected, while the light sensor adjusts the degree of roof opening to optimize the drying process when sufficient sunlight is available. With this intelligent solution, the efficiency and effectiveness of the clothesline roof utilization are improved, and clothes are optimally protected from rain exposure [5].

In 2023, Irawan Fery conducted a study entitled *"Smart Clothesline Using Fuzzy Logic for Weather Condition Monitoring Based on Mobile Application and Telegram"*. The research proposed an automatic clothesline system equipped with rain and LDR sensors, whose roof opens or closes automatically in response to sensor inputs to protect clothes from rain. Weather conditions were monitored in real time through a mobile application and Telegram [6].

In 2023, Zulkipli, Muhammad Asyraf, Khairul Huda Yusof, and Muhammad Auzi Herizal developed an automatic clothesline system equipped with an LDR sensor and a rain sensor to detect ambient light intensity and rainfall conditions. Data from these sensors is processed by a microcontroller to control a DC motor that moves the clothesline inward or outward automatically. The system also supports remote monitoring and control via a smartphone application using the Blynk platform. The results of this study demonstrate the successful implementation of an automatic clothesline prototype that uses light and rain sensors, combined with a motorized mechanism, to retrieve and deploy clothes efficiently [7].

2. System Planning

The system design involves several key steps:

Block Diagram System

The system planning for this research is done based on the diagram blocks that have been created, as shown in Figure 1 below:

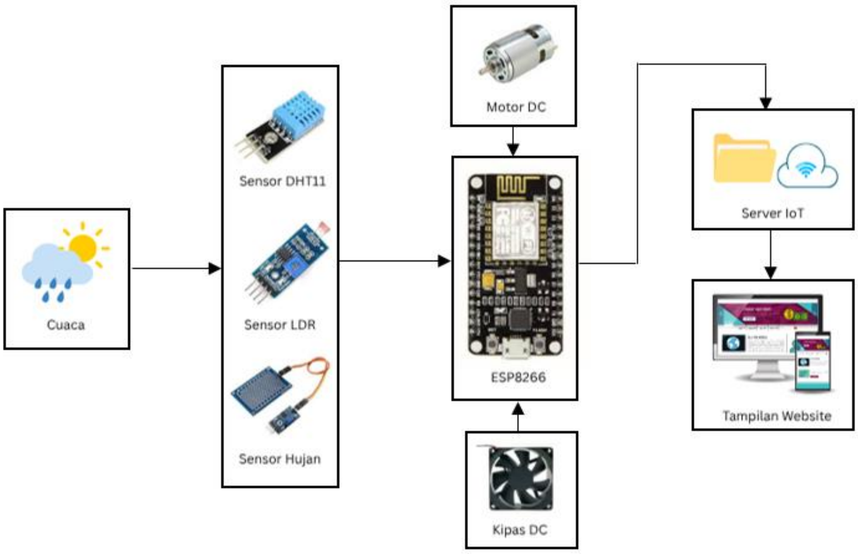


Figure 1. Block Diagram System

The system block diagram presents the overall workflow of the IoT-based automatic clothesline system. Weather conditions are first detected using a rain sensor, an LDR sensor, and a DHT11 sensor as input parameters. The acquired data are processed by the ESP8266, which employs a fuzzy logic approach to control the DC motor and DC fan based on environmental conditions. The system status and monitoring data are then transmitted to a server and displayed on a web interface, enabling real-time monitoring and control via a PC or smartphone [8].

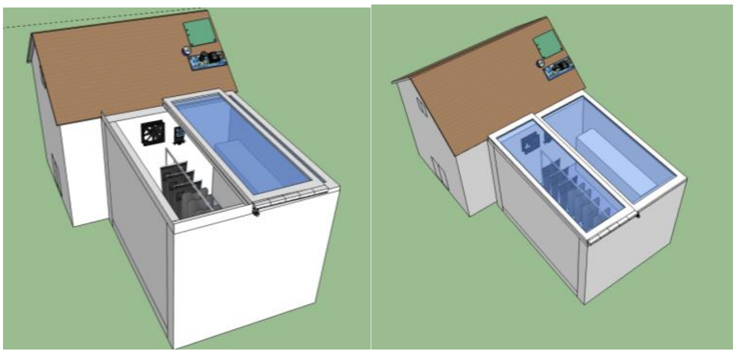


Figure 2. Prototype Hardware Design

The hardware prototype design focuses on the system's physical components and their functions. The prototype consists of an ESP8266 microcontroller integrated with a rain sensor, an LDR sensor, and a DHT11 sensor to collect environmental data. A DC motor operates the roof-opening and closing mechanism, while a DC fan supports the clothes-drying process. All sensor data are processed by the ESP8266 using fuzzy logic to control the actuators, and the resulting system data are sent to a server for display on a website accessible through a PC or smartphone [9].

3. System Testing

Tests were conducted to evaluate the performance of hardware components used in the system, including the rain sensor, LDR sensor, DHT11 sensor, DC motor, and DC fan. The testing process also involved evaluating the integration of the ESP8266 with the web-based system to ensure that data transmission, monitoring, and control functions operate correctly and reliably in real time.

4. Analysis

Test results are analyzed to evaluate system performance, sensor detection accuracy, and the responsiveness of data transmission to the web interface. The conclusion drawn from this analysis is that the designed automatic clothesline prototype is effective and reliable.

Table1. Main Device Specifications Used

No	Identity	Type	Main Specifications
1	ESP8266	NodeMCU ESP8266	Integrated Wi-Fi microcontroller, supports IEEE 802.11 b/g/n, operating voltage 3.3 V DC, VIN input 4.5–10 V, 10-bit ADC, multiple GPIO pins, programmable via Arduino IDE.
2	Rain Sensor	Raindrop Sensor Module	Detects rainfall using the water conductivity principle, analog and digital output, adjustable sensitivity, operating voltage 3.3–5 V DC
3	LDR Sensor	LDR Module (LM393)	Light intensity detection based on resistance variation, analog and digital

			output, adjustable threshold, operating voltage 3.3–5 V DC
4	DHT11 Sensor	Temperature and Humidity Sensor	Temperature range 0–50 °C, humidity range 20–90% RH, digital output, operating voltage 3.3–5 V DC
5	DC Motor	Gear DC Motor	Converts DC electrical energy into mechanical motion, operating voltage 6–12 V DC, used for the roof opening and closing mechanism
6	DC Fan	DC Cooling Fan	Provides airflow to accelerate the drying process, operating voltage 12 V DC, and low power consumption

C. Result and Discussion

After the planning and fabrication stages, several tests were conducted in this research. The testing process was carried out in phases: individual component testing, integrated system testing, and data transmission time testing to the web-based monitoring system.

1. Hardware System Implementation

The hardware implementation consists of an ESP8266 microcontroller connected to a combination of DHT11, LDR, and rain sensors to detect various weather conditions. The ESP8266 processes the detected data to generate control outputs for the DC motor and DC fan. The hardware implementation of the system is shown in Figure 3.

Figure 3. Hardware System Implementation

2. Rain Sensor Testing

Rain sensor detection testing was conducted to verify its ability to distinguish between rainy and non-rainy conditions. Two test scenarios were applied. In non-rain conditions, the sensor produced ADC values exceeding 10000 and voltages above 1.87 V, and the system displayed the status "No Rain". In rainy conditions, the sensor generated ADC values of 10000 or less with voltages of 1.87 V or lower, resulting in the status "Rain". The results indicate that the rain sensor accurately detects weather conditions [10].

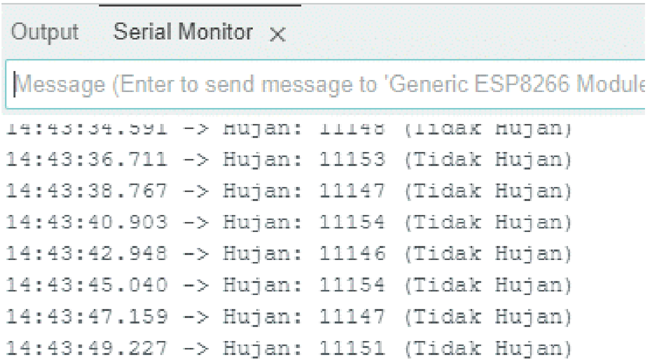


Figure 4. Rain Sensor Testing

Table 2. Rain Sensor Testing Data

Test Condition	Sensor ADC Value	Voltage (V)	Desription
No Rain Condition (>10000)	111153	2.09	Valid
Rain Condition (≤10000)	7619	1.43	Valid

3. DHT11 Sensor Testing

DHT11 sensor testing was conducted to verify its ability to detect environmental conditions across varying temperature and humidity levels. The testing included three temperature scenarios, namely low (20°C–26°C), normal (25°C–32°C), and high (30°C–40°C), as well as three humidity scenarios consisting of dry (40%–60%), normal (55%–80%), and humid (75%–100%) conditions. The results indicate that the DHT11 sensor operates reliably in measuring both temperature and humidity, providing accurate environmental data [11].

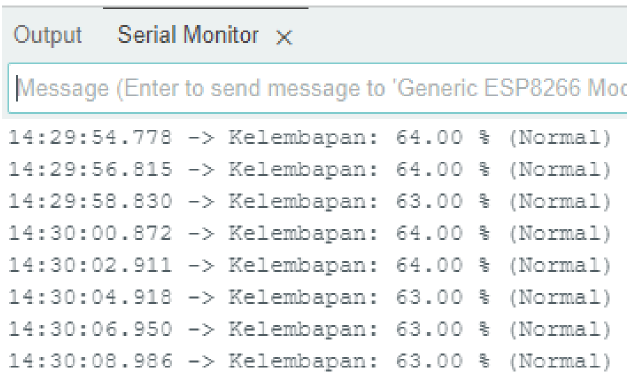


Figure 5. Rain Sensor Testing

Table 3. DHT11 Temperature Sensor Testing

No	Temperature Range (°C)	Measured Value (°C)	Status
1	20–26 (Low)	24.70	Valid
2	20–26 (Low)	25.00	Valid
3	25–32 (Normal)	30.40	Valid
4	25–32 (Normal)	31.20	Valid
5	30–40 (High)	33.55	Valid
6	30–40 (High)	33.70	Valid

Table 4. DHT11 Humidity Sensor Testing

No	Humidity Range (%)	Detected humidity (%)	Status
1	40–60 (Low)	45	Valid
2	40–60 (Low)	51	Valid
3	55–80 (Normal)	63	Valid
4	55–80 (Normal)	64	Valid
5	75–100 (High)	85	Valid
6	75–100 (High)	87	Valid

4. LDR Sensor Testing

LDR sensor testing was conducted to verify its ability to detect light intensity across dark-to-bright conditions. Testing was performed under three conditions: dark conditions with ADC values below 6000, normal light conditions with ADC values between 6000 and 8000, and bright conditions with ADC values above 8000. The results indicate that the LDR sensor reliably detects variations in light intensity, providing accurate environmental lighting information [12].

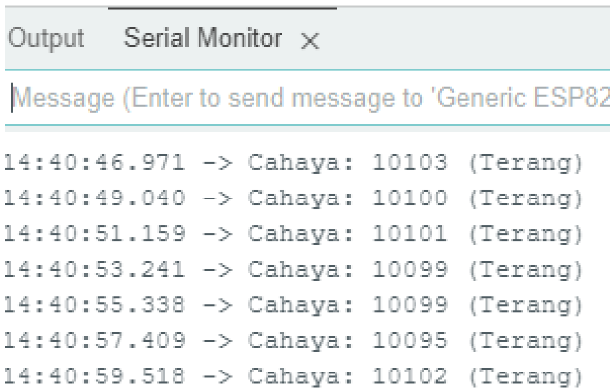


Figure 6. LDR Sensor Testing

Table 5. LDR Sensor Light Testing

Test Condition	LDR Value (ADC)	Voltage (V)	Light Intensity (Lux)	Status
Dark Condition	5751	0.65	45	Valid
Normal Light Condition	7318	0.89	120	Valid
Bright Light Condition	10103	1.10	300	Valid

5. System Integrated with Fuzzy Logic Testing

Fuzzy-logic system testing was conducted to evaluate how the system determines control outputs for the DC motor and DC fan as a function of input variables, including temperature, humidity, light intensity, and rain intensity. In this system, the fuzzy logic method processes the input data to generate output in the form of operation duration (seconds) for the DC motor movement to close the roof and for the DC fan to assist the drying process [13].

Table 6. Fuzzy Logic Integration Testing

No	Weather Condition	Light Intensity (ADC)	Rain Intensity (ADC)	Temperature (°C)	Humidity (%)
1	Bright light, rain, high temperature, humid	8916	7721	33.60	78
2	Bright light, no rain, normal temperature, normal humidity	8267	11955	27.60	60
3	Dark light, no rain, low temperature, dry humidity	3821	10981	23.50	47
4	Normal light, rain, high temperature, normal humidity	6380	8199	33.70	61
5	Bright light, no rain, low temperature, humid	9761	10329	23.80	85

Table 7. Output Fuzzy Logic Integration Testing

Test Condition	Fuzzy Output	DC Motor Duration (s)	DC Fan Duration (s)
1	Roof closed, fan ON	1	10
2	Roof open, fan OFF	1	0

3	Roof closed, fan OFF	1	0
4	Roof closed, fan ON	1	10
5	Roof open, fan OFF	1	0

Based on the conducted tests, the fuzzy logic system implemented in the automatic clothesline operates adaptively, responsively, and stably to determine roof and fan conditions based on four environmental parameters: light intensity, rainfall, temperature, and humidity [14].

6. Website System Testing

The website was developed to display data obtained from sensor detection. In addition, the website presents sensor data graphically and stores historical sensor data. The website also provides a manual control feature to operate the DC fan and DC motor for roof movement [15].

1. Main Page

   The main page displays real-time sensor data, enabling users to monitor environmental conditions and current weather conditions. The displayed data indicate a high temperature of 33.3 °C, a dry humidity of 55%, a rainfall intensity of 11097 (indicating no rainfall), a bright light intensity of 8448, and system conditions with the roof open and the fan off.

Figure 7. Main Page Website

2. Graph Page

   The graph page visualizes all sensor data using four time-series graphs, each representing one input parameter. The data are refreshed every 5 seconds and reset every 1 hour.

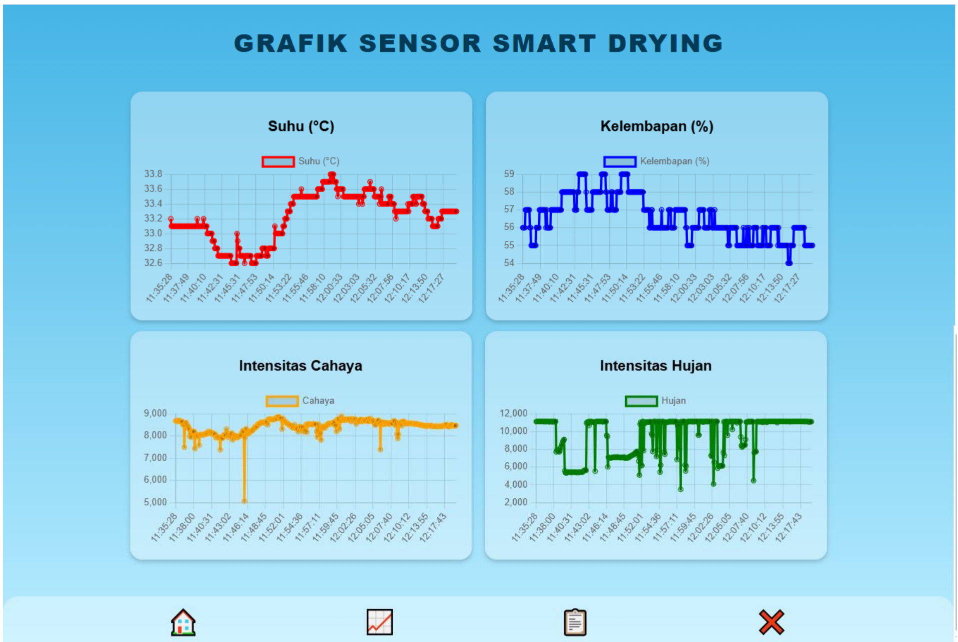
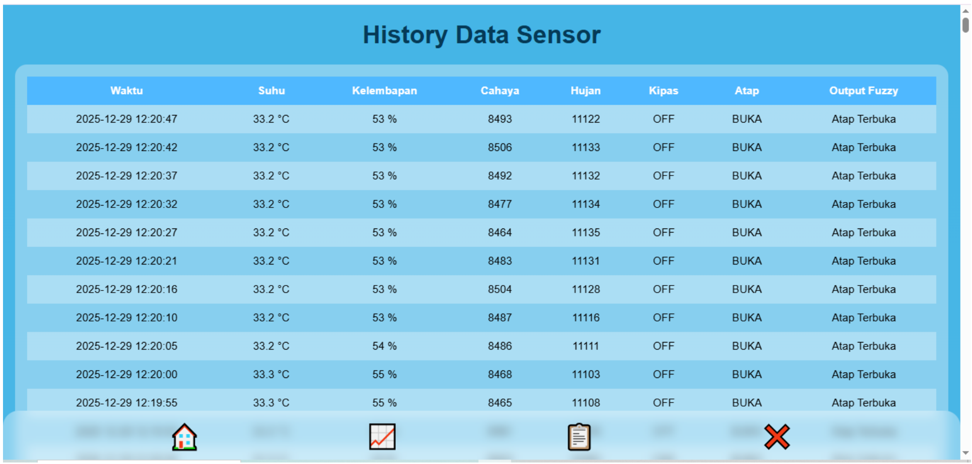


Figure 8. Graph Page Website

3. History Page

The history page provides a log of sensor measurements stored in the database, along with the resulting roof and fan operations. The data are refreshed every 5 seconds and reset every 1 hour, as shown in the graph visualization.



History Data Sensor

Waktu	Suhu	Kelembapan	Cahaya	Hujan	Kipas	Atap	Output Fuzzy
2025-12-29 12:20:47	33.2 °C	53 %	8493	11122	OFF	BUKA	Atap Terbuka
2025-12-29 12:20:42	33.2 °C	53 %	8506	11133	OFF	BUKA	Atap Terbuka
2025-12-29 12:20:37	33.2 °C	53 %	8492	11132	OFF	BUKA	Atap Terbuka
2025-12-29 12:20:32	33.2 °C	53 %	8477	11134	OFF	BUKA	Atap Terbuka
2025-12-29 12:20:27	33.2 °C	53 %	8464	11135	OFF	BUKA	Atap Terbuka
2025-12-29 12:20:21	33.2 °C	53 %	8483	11131	OFF	BUKA	Atap Terbuka
2025-12-29 12:20:16	33.2 °C	53 %	8504	11128	OFF	BUKA	Atap Terbuka
2025-12-29 12:20:10	33.2 °C	53 %	8487	11116	OFF	BUKA	Atap Terbuka
2025-12-29 12:20:05	33.2 °C	54 %	8486	11111	OFF	BUKA	Atap Terbuka
2025-12-29 12:20:00	33.3 °C	55 %	8468	11103	OFF	BUKA	Atap Terbuka
2025-12-29 12:19:55	33.3 °C	55 %	8465	11108	OFF	BUKA	Atap Terbuka

Figure 9. History Page Website

4. Manual Control Page

The manual control page enables manual operation of the roof and fan through dedicated control buttons. An *auto-fuzzy button is provided to restore fuzzy*-logic–based automatic control after manual intervention.

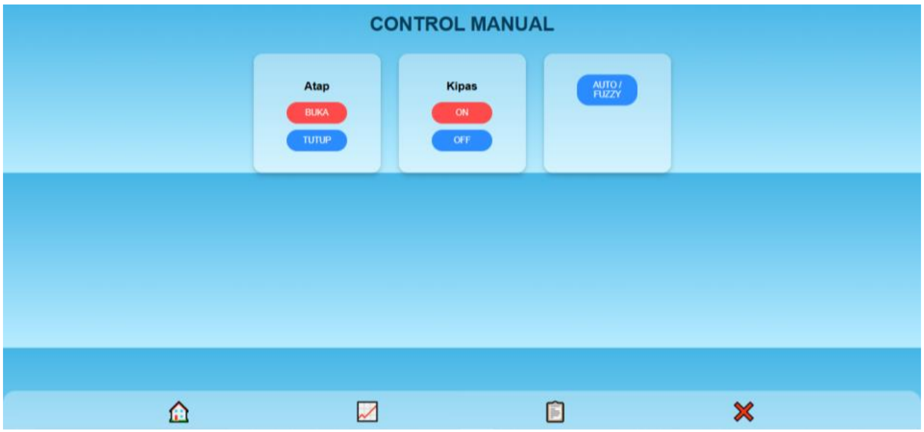


Figure 10. Manual Control Page Website

D. Conclusion

The proposed automatic clothes drying system can control the roof and DC fan in both automatic and manual modes based on environmental conditions, while providing real-time monitoring via a web-based interface. The rain sensor, LDR, and DHT11 sensor operated accurately and stably, enabling reliable detection of rainfall, light intensity, temperature, and humidity. All sensors and actuators were successfully integrated, allowing the system to process multiple inputs simultaneously and generate consistent control actions. The implemented fuzzy logic method, with 54 rules, produced adaptive decisions for roof movement and fan operation, with the DC motor and DC fan responding correctly to the predefined activation durations. In addition, the web interface functioned properly, displaying real-time data, graphical visualizations, and historical records, and providing manual control features.

E. Acknowledgment

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