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Prototype of Automatic Cover Roof Control system for Grain Drying Based on Internet of Things (IoT)

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ABSTRACT

The sun is the largest source of heat energy on earth. Sunlight as an energy source can be used for the drying process in drying grain. Grain drying is done by drying in the open field or often referred to as traditional drying. Drying using sunlight has weaknesses, including if the weather changes, such as sudden rain, it will be difficult to move the grain. As a result, the dry grain becomes wet again so it takes more time to dry. From these problems, this research makes an automatic roof design when it rains, the roof will be closed automatically. If the weather is sunny and it is not raining, the roof will open. The sensors used are rain sensors and LDR sensors as light sensors that can produce several weather outputs such as sunny, cloudy and dark. While the material used is like a motor to be able to move the pulley. And the motor will move after getting instructions from the NodeMCU that the light received from the light sensor is in accordance with the command then the motor will move and the pulley will lift the light and strong plastic roof to be able to cover the roof perfectly after the rain sensor works. System testing shows an error in light of 5.5% while the system error shown at temperature is 0.01% and an error in humidity is 0.11%. The ability of the system to cover the roof when it is cloudy or when it is raining.

1. Introduction

Technology is currently developing rapidly. One of the main factors of a country's progress is food security. Technological advancements are making activities [1] more convenient. Sunlight plays a crucial role in the food drying industry, particularly in the process of sun-drying. Sun-drying is a common daily activity, not only for drying clothes, mattresses, rice, etc., but also in various production industries such as rice production, cracker production, salted fish, and others. Sunlight, as an energy source, is utilized for the drying process in sun-drying rice [2]-[4]. Indonesia experiences different seasons based on the frequency of rainfall, known as the rainy season and the dry season. The sun is the Earth's largest source of heat energy, allowing plants to produce oxygen vital for humans and animals. Without the sun, the Earth would freeze. It is an easily accessible and cost-free energy source [5]-[9].

The Internet of Things (IoT) is a new technological paradigm envisioned as a global network of machines and devices capable of interacting with each other. IoT is considered one of the most important areas of future technology and has garnered widespread attention from various industries. The true value of IoT for companies can be fully realized when connected devices can communicate with each other and adapt to changing environmental conditions, such as poor water quality [10]-[15].

Water is vital for all living beings in the aquatic world. It is essential for humans, animals, plants, and the environment. Water also plays a role in determining soil quality as a growing medium and serves as irrigation for farmers [16][17]. Continuous rice cultivation leads to environmental changes due to poor water quality. Household and industrial waste pollution has resulted in a decline in water quality in rice farming, negatively impacting environmental quality [18]. Rice drying is traditionally carried out through sun-drying in open fields. This method has its drawbacks, such as difficulty in moving the rice when sudden weather changes occur, such as unexpected rain, especially if there is no one present to monitor the process. Consequently, partially dried rice becomes wet again, necessitating more drying time [19]. To address this issue, a system is needed that can dry rice using direct sunlight but can automatically close the roof in case of weather changes. This system can be controlled and monitored remotely through Blynk [20].

Given these issues, the author aims to design an automated roof that closes when it rains and opens during sunny weather. The sensors used in this system are rain sensors and LDR sensors (light sensors), which can detect different weather conditions such as clear, overcast, and dark.

2. Method

2.1. System Design

There are several components and materials used, such as a motor to move the pulley. The motor will activate upon receiving instructions from the NodeMCU that the light received from the light sensor corresponds to its command. The motor will then move, and the pulley will lift the lightweight and sturdy plastic roof to close it perfectly after the rain sensor functions.

2.1.1. Software Design

The diagram begins with initialization, followed by input from the light sensor, which is processed and translated into statements. If the light sensor's output is HIGH (bright), the roof opens. If the output is anything other than HIGH or LOW, the roof closes. This explanation can be seen in the flowchart presented in Fig. 1.

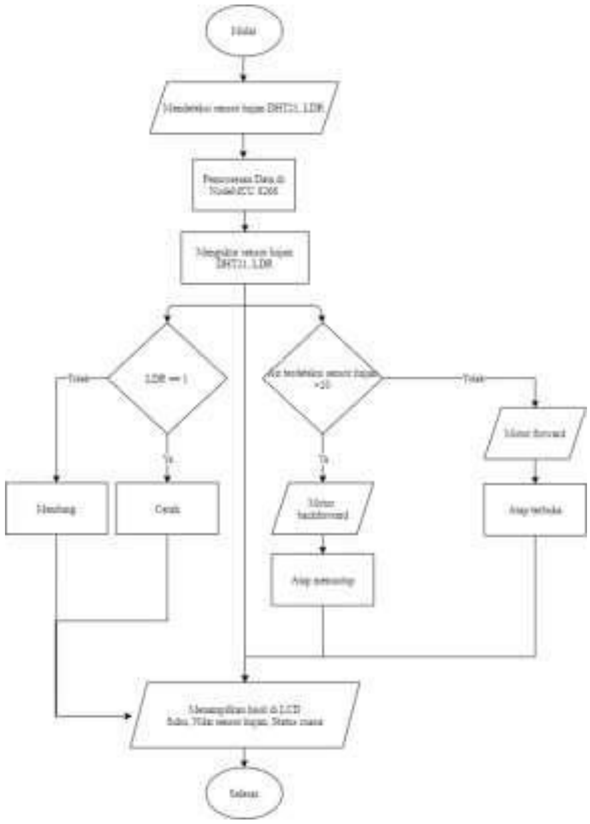


Fig. 1. Flowchart

2.1.2. Hardware Design

The research design includes a system block diagram. This block diagram assists in the creation of both software and hardware designs. The overall system block diagram can be seen in Fig. 2.

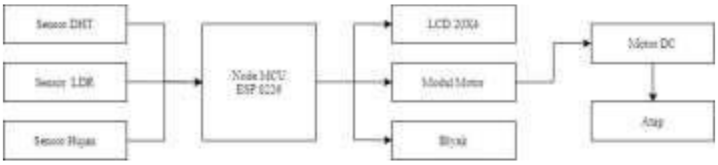


Fig. 2. Block Diagram

Based on the block diagram, when sunlight is bright, the NodeMCU will execute and instruct the motor to remain stationary. If the sunlight becomes dim or indicates rain, the NodeMCU will execute and instruct the motor to move, which activates the pulley to close the roof.

In the Prototype Design Fig. 3 and Fig. 4, there are several components and materials used, such as a motor to move the pulley. The motor will activate upon receiving instructions from the NodeMCU that the light received from the light sensor corresponds to its command. The motor will then move, and the pulley will lift the lightweight and sturdy plastic roof to close it perfectly after the rain sensor functions.

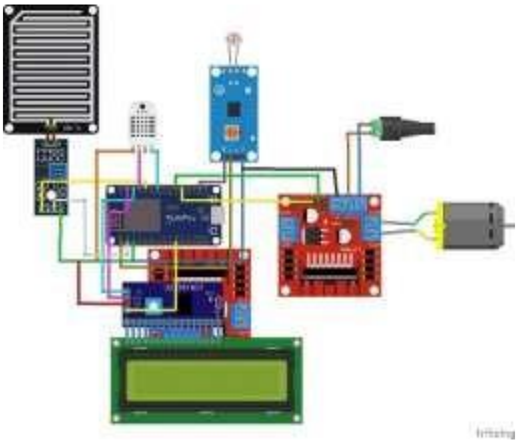


Fig. 3. System Wiring Design

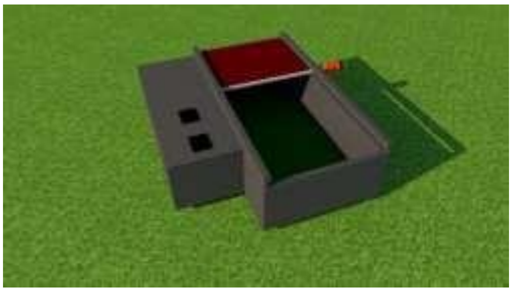


Fig. 4. Automated Roof Design

3. Results and Discussion

3.1. DHT11 Sensor Testing

The testing of the rain sensor aims to determine whether the rain sensor works properly or not. The rain sensor is tested by dripping water onto the sensor panel. The results of the test, as shown in Table 1, indicate that the sensor responds to the presence or absence of water dripping on it. It can be concluded that the working principle of this sensor is that when water comes into contact with the sensor panel, it causes electrolysis, resulting in logic 0 and 1 states. Since water is an electrolyte, a substance that can conduct electricity, even in small amounts, this process activates the DC motor to automatically close the roof.

Table 1. Rain sensor testing

Condition	Roof
Wet	Closed
Dry	Open

3.2. LDR Sensor Testing

The LDR sensor testing compares the actual light intensity (output of the LDR sensor) with the measured light intensity using a Luxmeter. The goal of this test is to obtain the percentage of error, which is useful for analyzing whether the LDR sensor is in good condition and ready for use, as well as to determine the sensitivity and accuracy of the LDR sensor.

Table 2 shows the data from the LDR sensor testing against the comparing measurement tool (Luxmeter). The table explains that the light intensity changes continuously depending on the location with high or low light intensity. The brighter the light, the higher the value of the light intensity produced. The results of the light intensity measurements show that the Luxmeter's light intensity value is smaller than the light intensity value from the LDR sensor. This difference is due to the LDR sensor not having the same light intensity focusing capabilities as the Luxmeter, resulting in the LDR sensor receiving less or less accurate light intensity. The next step is to calibrate the LDR sensor with the Luxmeter to determine the error value of the LDR sensor. The error value from this sensor calibration can be calculated using equations (1) and (2).

Table 2. Data of LDR sensor testing against the comparing measurement tool (luxmeter)

No	Light intensity	Lux Meter	Error (%)
1	5994	5450	0.09982
2	4155	3610	0.15097
3	5584	5040	0.10794
4	8454	7910	0.06877
5	4264	3720	0.14624
6	5994	3410	0.75777
7	3083	2540	0.21378
8	1821	1277	0.426
9	1480	936	0.5812
10	1619	1075	0.50605
11	1332	788	0.69036
12	642	98	5.55102
Average Error			5.565084

$$Difference = |Reference\ Value - Sensor\ Value| \tag{1}$$

$$Error\ presentation = \frac{Error\ presentation}{|Reference\ Value|} \times 100\% \tag{2}$$

The data obtained from the above measurements shows that the average error is 5.565084%.

The sensor will detect both bright and dark conditions, indicating day and night. If there is a high light intensity, during the day, the roof will automatically open. Similarly, if the light intensity decreases, indicating nighttime, the roof will automatically close can be seen in Table 3.

Table 3. LDR testing

Condition	Roof
Bright	Open
Dark	Closed

3.3. DHT22 Sensor Testing

The testing of the DHT22 sensor aims to measure its ability to receive changes in the measured parameters, namely temperature and humidity. This testing involves comparing the measured temperature and humidity using a simple temperature and humidity measurement tool with the data displayed on Blynk and the LCD.

The DHT22 testing is performed by comparing the readings of the DHT22 sensor with a thermometer, as shown in Table 4, and with a hygrometer, as shown in Table 5. The testing is carried out twelve times for both temperature and humidity measurements, and the differences between the DHT22 sensor readings and the thermometer/hygrometer are small. Table 4 contains data on temperature readings with an average error of 0.013231°C, which is caused by the calibration difference between the thermometer and DHT22. Table 5 contains data on humidity readings with an average error of 0.11957%, which is caused by the calibration difference between the hygrometer and DHT22.

Table 5 shows the results of the DHT22 sensor in measuring temperature and humidity using the NodeMCU microcontroller. After the DHT22 sensor functions properly, the next step is to calibrate the DHT22 sensor with a temperature and humidity detector. This calibration is done to determine the error value of the DHT22 sensor and LDR sensor. The error value from this sensor calibration can be calculated using equations (1) and (2).

Table 4. DHT22 sensor testing – temperature

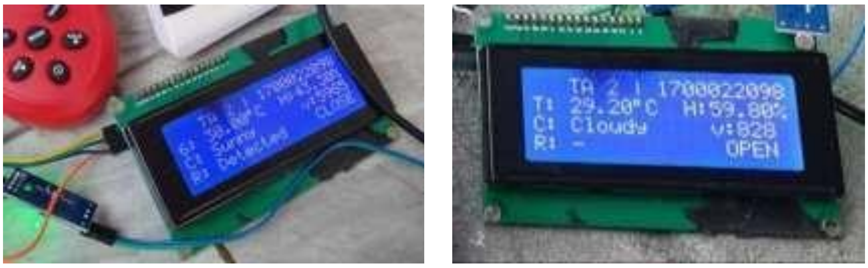
No	Temperature Value (°C)	Thermometer (°C)	Error (%)
1	32	32.2	0.006211
2	32.4	32.7	0.009174
3	31.6	32.0	0.0125
4	33.1	32.5	0.01846
5	31.2	31.6	0.012658
6	31	31.3	0.009585
7	30.8	31.2	0.012821
8	30.2	30.2	0
9	30.2	29.9	0.01003
10	29.9	29.5	0.01356
11	29.4	29.2	0.00685
12	28.7	28.5	0.00702
Average Error			0.013231

Table 5. DHT22 sensor testing - humidity

No	DHT22 Moisture Value (%)	Hygrometer (%)	Error (%)
1	34.2	36	0.05
2	33.2	35	0.051429
3	35	36	0.027778
4	33.2	36	0.077778
5	37	37	0
6	39	39	0
7	39.3	40	0.0175
8	41.3	42	0.016667
9	41.3	43	0.039535
10	43.2	44	0.018182
11	45.3	45	0.00667
12	49.2	46	0.06957
Average Error			0.11957

3.4. LCD (Liquid Crystal Display) Testing

The LCD testing is essential for displaying information during the device testing. All notifications executed by the system through program commands are displayed on the LCD. The display during LCD testing is shown in Fig. 5 (LCD Close) and (LCD Open). The LCD displays various information, such as temperature, humidity, cloud condition, light intensity value, and rain detection.



(a) (b)

Fig. 5. (a) LCD Display (Closed Roof) and (b) LCD Display (Open Roof)

3.5. Motor Driver Testing

The motor used is a DC motor. A DC motor is a machine that converts electrical energy into mechanical energy, resulting in the rotation of the motor. To drive the DC motor, another component is needed as a signal current amplifier from the NodeMCU. The L298 current driver is used for this purpose.

In this testing, the servo motor functions as the automatic roof opener and closer. The servo motor will move to close and open the roof based on whether it's raining, daytime, or nighttime. If it's rainy or nighttime, the microcontroller will send signals or commands to the servo motor to automatically close the roof. Similarly, if it's daytime, the microcontroller will send signals or commands to the servo motor to automatically open the roof.

3.6. Internet of Things (IoT) Testing

The IoT research is conducted using Blynk. The IoT testing aims to assess the data receiving capability of Blynk. Blynk is a smartphone application used to create commands, displays, and data display dashboards received from NodeMCU. The data sent includes temperature, humidity, cloud condition, rain status, light intensity value, and roof condition shown in the Fig. 6.

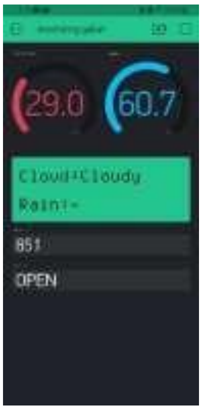


Fig. 6. Blynk Display

3.7. Equipment Circuit

The complete hardware circuit includes an LCD display on the top of the component house, which will display temperature, humidity, cloud condition, light intensity, and roof condition. Additionally, there is a rain sensor that detects the presence of water shown in the Fig. 7.

Fig. 7. Component House

Fig. 8 shows the prototype display of the automatic roof for drying rice. Beside the prototype, there are housing units used to store components. The roof prototype used is made of plastic for ease of rolling.

Fig. 8. Automatic Roof Prototype

3.8. Drying Rice Roof Cover Monitoring Results

The system has been designed and tested. After conducting tests on each component, the final step was to perform a comprehensive simulation of the entire device. The testing was carried out from 11:00 to 17:00. The results obtained include temperature, humidity, light intensity value, rain condition, cloud condition, and roof condition. The testing data results can be seen in Table 6.

Table 6. System testing results

No	Time	Temperature Value (°C)	Rated Moisture (%)	Light intensity	Rain Conditions	Cloud Conditions	Roof Condition
1	11.00 – 11.30	32	34.2	5994	–	Sunny	Open
2	11.30 –12.00	32.4	33.2	4155	–	Sunny	Open
3	12.00 – 12.30	31.6	35	5584	–	Sunny	Open
4	12.30 – 13.00	33.1	33.2	8454	–	Sunny	Open
5	13.00 – 13.30	31.2	37	4264	–	Sunny	Open
6	13.30 – 14.00	31	39	5994	–	Sunny	Open
7	14.00 – 14.30	30.8	39.3	3083	Detected	Sunny	Close
8	14.30 – 15.00	30.2	41.3	1821	Detected	Cloudy	Close
9	15.00 – 15.30	30.2	41.3	1480	Detected	Cloudy	Close
10	15.30 – 16.00	29.9	43.2	1619	Detected	Cloudy	Close
11	16.00 – 16.30	29.4	45.3	1332	Detected	Cloudy	Close
12	16.30 – 17.00	28.7	49.2	642	Detected	Cloudy	Close

3.9. Roof Cover Control Results for Drying Rice

The roof control system was tested using a servo motor to move the roof. The roof will close if the rain sensor detects rainwater or during night time conditions, as shown in Fig. 9. During daytime and no rain is detected, the roof will open, as shown in Fig. 9.

(a) (b)

Fig. 9. (a) Closed roof and (b) Open roof

4. Conclusion

After designing the prototype and testing the device and system as a whole, the conclusion of this study is that the first LDR sensor can be connected to NodeMCU to read light intensity values and can be displayed on the LCD and sent to Blynk. The rain sensor can be connected to NodeMCU to detect rain and can be displayed on the LCD and sent to Blynk. The DHT22 sensor can be connected to NodeMCU to read temperature and humidity values and can be displayed on the LCD and sent to Blynk. The microcontroller is able to properly process the input from each sensor, so that it produces output in the form of: opening and closing the roof. Blynk is working fine being able to receive data from NodeMCU.

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