Research Article

Implementation of Smart Farming for Oyster Mushroom Cultivation Based on Wireless Sensor Network Using ESP8266

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Abstract:
Internet of Things (IoT) technology can facilitate daily work in various fields. This study aims to implement smart farming for oyster mushroom cultivation based on Wireless Sensor Network (WSN) and ESP8266. The sensors used are temperature and humidity sensors with NodeMCU ESP8266 as a microcontroller so that they can take advantage of the Internet of Things (IoT) concept. The prototype tool is designed in the form of a prototype box. The prototype box has two rooms that aim to apply the Wireless Sensor Network (WSN) method so that data in each different room can be retrieved and then sent the data to the website. Tests were carried out to measure the comparison of temperature and humidity sensors with manual measurement tools. The results of this study show an absolute error average of 0.606% for temperature data and an absolute error of 0.627% for humidity data. This indicates that the overall system is excellent and responsive.

Keywords: Smart Farming, IoT, Wireless Sensor Network (WSN), ESP8266

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1. INTRODUCTION

The development of technology and science has attracted a lot of attention, especially electronics which continues to develop with sophisticated tools designed to help with daily tasks that are sometimes difficult and require high concentration and accuracy. One of the uses of technology is to create a device or system that can work automatically to facilitate every human activity [1]. Urban Farming is a term that refers to agricultural activities carried out in urban areas [2]. One of the urban farming activities is oyster mushroom cultivation. Oyster mushroom is a wood mushroom with many health benefits and is popular with the public [3].

Monitoring and controlling environmental variables of oyster mushroom cultivation is done manually by farmers [4]. Oyster mushroom farmers normalize temperature and humidity manually, for example, by watering mushrooms with high air intensity [5]. The ideal room temperature is 22-28ºC, and the humidity is 70-90% [6]. Research on oyster mushroom cultivation has been carried out before, including by [7] using Arduino and LabVIEW software. Users can send messages about changes in conditions at any point in the oyster mushroom room, by the rules of mushroom farmers.

The intelligent monitoring system also records data in real-time via Excel, and the data collection results are automatically sent via an email system developed at LabVIEW. However, in this study, there were drawbacks, namely, being able to monitor temperature and humidity through an application without normalizing temperature and moisture, such as automatic watering. Research by [8] applies the Internet of Things (IoT) to help oyster mushroom cultivators automatically water the oyster mushroom beetles with the NodeMCU ESP8266 module and the Blynk application, making it easier to monitor the pump status, humidity, and temperature of the oyster mushroom house. This research makes it possible to create automatic sprinklers and monitoring applications to monitor the humidity and temperature of oyster mushrooms. There is a deficiency in this study where monitoring results do not have notifications regarding conditions in the oyster mushroom cultivation room, as well as control arrangements to maintain the stability of ideal parameters so that conditions for oyster mushrooms do not exceed ideal parameters. Moreover, at study [9] covers the weaknesses of previous research, which used the ESP8266 and the ATmega328 microcontroller on the Arduino Uno to monitor in real-time and set the On-Off relay for watering control. The results showed that the system was running according to the initial design, but there were deficiencies in this study; namely, there was only one sensor located at 1 point in the room, so it was less accurate in monitoring the mushroom room when the oyster mushroom room had differences in temperature and humidity between points.

Based on the problems in this study, the researchers took the initiative and were interested in optimizing the previous research. Research on the development of a Smart Farming system for Oyster Mushroom Cultivation Based on a Wireless Sensor Network (WSN) Using ESP8266 is expected to be able to complete the deficiencies of previous studies. Wireless Sensor Network (WSN) is a network with unique advantages that can connect sensor node devices located at specific points or areas and use wireless media as data communication between nodes [10]. The sensors used in this study are temperature and humidity sensors (DHT22) with the NodeMCU ESP8266 as a microcontroller so that it can also take advantage of the Internet of Things (IoT) concept because the NodeMCU ESP8266 is equipped with Wi-Fi modules [11]. The Internet Of Things (IoT) is a concept where an object can transmit data over a network without direct contact [12].

2. THEORY

Sensors are components or modules that aim to detect certain conditions or changes in the environment and then send that information to other devices. Wireless Sensor Network (WSN) is a wireless network that functions as a link between nodes [13]. Wireless Sensor Networks are distributed autonomous devices that use sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, and movement in different locations [14]. WSN can be used to collect data and discover systems. Furthermore, the Internet of Things (IoT) is a concept or program of an object with advantages that can facilitate daily life, with the working principle of transmitting or transferring network data without using human and computer power. IoT is an advanced technology that is a combined information framework that is put together to enable innovative applications, including computer science, communications, microelectronics, and sensor technology [15].

Furthermore, Raspberry Pi is a mini-computer developed by the Raspberry Pi Foundation in England. This research uses the Raspberry Pi mini-computer; on the Raspberry Pi, several advantages are equipped with Wi-Fi, Bluetooth, and USB boot capabilities onboard and installed by bundling [16]. Like a computer, raspberries can run office programs or other programs like on a computer; it's just that the Raspberry Pi is equipped with input and output pins that support the power of this mini-computer that we can use to interact with sensors and other modules [17]. The central operating system of Raspberry Pi uses Debian GNU/Linux, and the programming language is Python. Moreover, The NodeMCU ESP8266 facilitates the development of devices offered by well-known and widely used development boards such as the Arduino Uno and Nano. Still, with a Wi-Fi module integrated into a single board [18], it is easy for users to develop Internet of Things-based devices. The NodeMCU is equipped with a micro-USB connector for programming and powering and comes with a push button reset and a flash button [18].

3. METHOD

This research has a design of a Wireless Sensor Network system that is expected to have reliable capabilities in receiving and storing data sent by sensor nodes [19] and sending back the data packets to the website database using the MQTT protocol publish method [20]. Users can get this data in real-time by using the MQTT protocol subscribe plan [21]. Furthermore, The Wireless Sensor Network (WSN) is a wireless network that links nodes and then forwards them to a device or system, such as a storage database server [22]. Wireless sensor networks consist of specialized sensor nodes with acquisition and computer-aided capabilities that can detect and monitor physical parameters and send the collected data to a central location via wireless communication [23]. Based on Figure 1, the system consists of 2 parts: sensor nodes and sink nodes, moreover, to obtain temperature and humidity data, two sensor nodes are made, including NodeMCU ESP8266 and DHT11 sensors. The sink node is a Raspberry Pi that becomes a data storage server. Data transmission from the sensor node to the sink node uses the MQTT protocol.

The software system in this research is a flow chart that will carry out system functions. The software system consists of 2 parts, namely, the automatic watering system and the monitoring website system. The ESP8266 microcontroller uses the Arduino IDE programming language to create programs and uses the PHP programming language for website programs with the help of the XAMPP application. XAMPP is a PHP, Apache, and MySQL installation package, so this application can be installed in PHP, Apache, and MySQL [24].

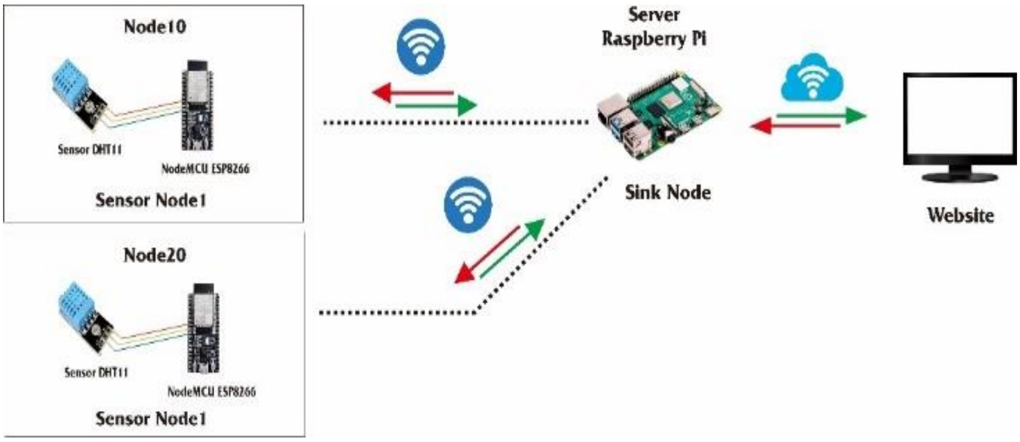

Figure 1. Design of WSN System

The flow chart for the automatic watering program is shown in Figure 2 (a). The watering pump will automatically turn on when the DHT11 sensor detects a temperature >28°C or humidity <70%. The pump will automatically stop watering if the temperature is ≤28°C or the humidity is ≥70%. In addition to watering, this system can also monitor the status of the temperature and humidity of the barn in real time through the website shown in Figure 2(b). The flowchart of the monitoring website shows the steps taken by the manager to monitor the temperature and humidity of the oyster mushroom baglog on the website; before the manager conducts monitoring, the manager must first log in by entering the username and password; if the login is successful, it will enter the dashboard page, and when the login fails, the username and password must be entered again until the login is successful. After the manager logs in, he will enter the website dashboard page; then, the manager chooses the monitoring menu on the website sidebar to monitor the temperature and humidity in the oyster mushroom baglog room. Managers can also manually control watering and activate FanDC on the website.

Furthermore, The hardware system design for the sensor nodes in this study is shown in Figure 3. The hardware consists of a microcontroller in the form of ESP8266, DHT11 temperature and humidity sensors, a solenoid valve as a watering tap, a dc fan as a temperature control fan, a 12V adapter as a power supply, and step-down lm2596 as a voltage reducer because the ESP8266 microcontroller can only receive a maximum voltage of 5V [25].

When viewed electrolytically, the hardware design can be seen in Figure 4. Schematic Capture in the proteus application shows the electronic circuit by connecting all components and sensors [19]. Pin VIN is used as a DC voltage input to the element, pin G is used as a negative voltage input to the component, pin D6 is used as reading and sending DHT11 sensor data, pin D2 is used as reading the input and output of Fan DC, pin D4 is used as reading the input and output of Solenoid Valve.

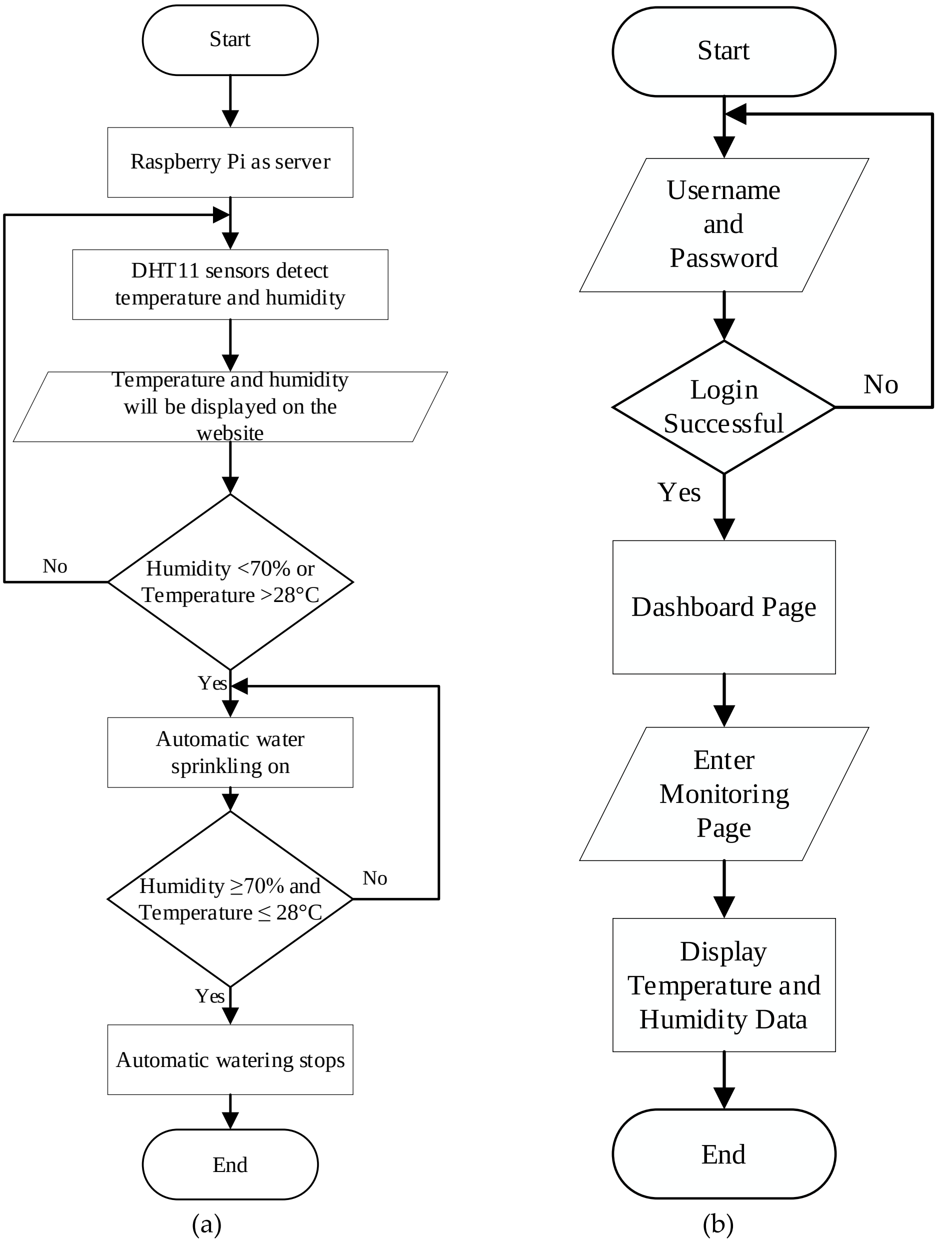

Figure 2. (a) Flowchart of Automatic Watering (b) Flowchart of WEB Monitoring

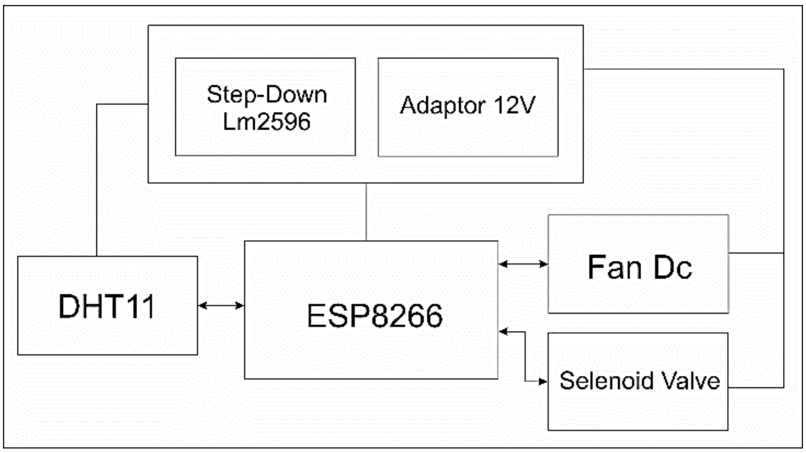

Figure 3. Sensor Node Architecture

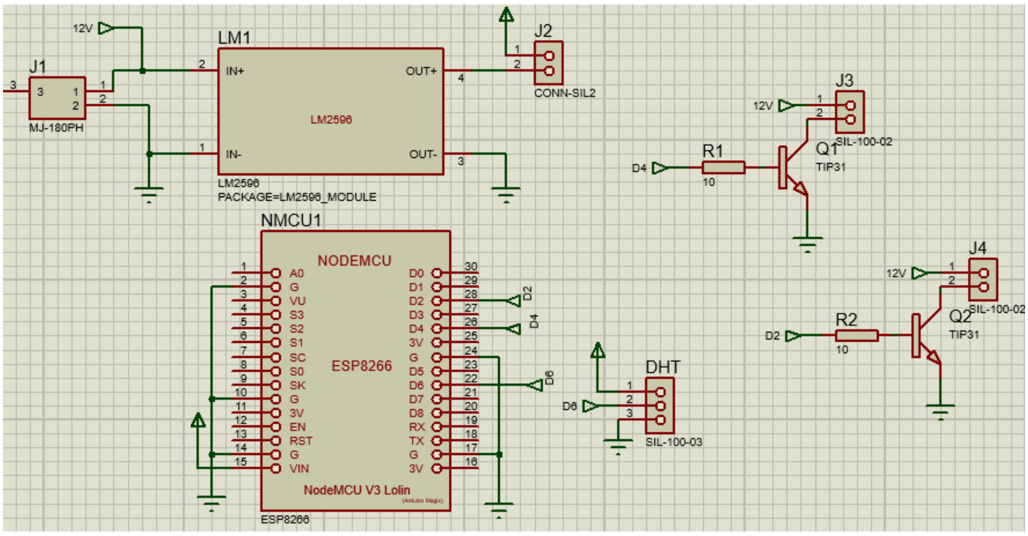

Figure 4. Schematic Capture Sensor Node

The overall architecture of the prototype tool is shown in Figure 5. The main system consists of a monitoring and control system. The working principle of this tool is that it has two microcontrollers because it applies the concept of a Wireless Sensor Network (WSN); the DHT11 sensor will detect the temperature and humidity in the oyster mushroom cultivation barn then the NodeMCU ESP8266 will send temperature and humidity information to the Raspberry Pi as a server then display temperature and humidity data on the website. If the temperature and humidity are lower, the solenoid valve will automatically open, and then the sprinkler releases water to neutralize the moisture, and vice versa. If the humidity exceeds the standard limit (excessive humidity), then information is sent to the monitoring website that the moisture is excessive; then, the farmer can turn on the DC Fan so that a lot of air will enter the mushroom barn to neutralize the humidity. The Raspberry Pi server will send information updates on the website in real-time [26].

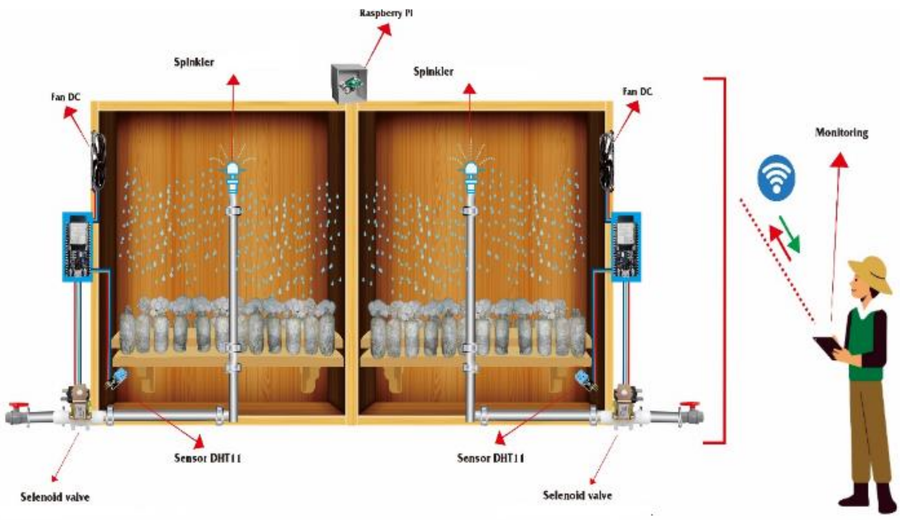

Figure 5. Design of Prototype

4. RESULT AND ANALYZES

This research tests the system in 2 stages: first, the test scenario stage will compare the measurement results from the *thermo hygro* humidity temperature gauge with the data from the DHT11 sensor displayed on the monitoring web; second, the overall prototype testing stage.

Furthermore, for three hours, data taken every 10 minutes of trial in the form of DHT11 sensor testing displayed on the monitoring website will be compared with temperature and humidity measuring devices, namely *thermo hygro*. Filling in the temperature and humidity comparison table uses the absolute percentage error calculation following equation 1.

$$\Delta X = \left(\frac{Xo-X}{X}\right).100\% \quad (1)$$

ΔX = Absolute error
Xo = Measurement value
X = Actual value
The interpretation of the absolute error (%) feasibility value is used:
0% - 25% = Success
25% - 50% = Enough
50% - 75% = Less Success
75% - 100% = No success

The measurement value will be taken from the DHT11 sensor value and website monitoring, and the actual value will be taken from the measurement results of the *thermo hygro* tool. Test data is produced from these tests, which will support the overall conclusion.

Moreover, The procedure for conducting tests is as follows. Testing is carried out using a prototype box designed according to the state of the oyster mushroom baglog room. There are 2 different rooms in the prototype box. Automatic watering parameters are >28°C, and automatic DC Fan activation at parameters >90%. Data is taken every 10 minutes for 3 hours of trial. The test procedure makes it easier for researchers to analyze research data. The test results can be seen in Table 1 and Table 2.

Table 1. Testing Data for Room A

No.	Time	[1] *Thermo hygro*		[2] Monitoring Web		Difference		$\Delta X(\%)$		Status
		T	H	T	H	T	H	T	H	
1	13:40	28°C	83%	27°C	83%	1°C	0%	3,57%	0%	
2	13:50	27°C	81%	26°C	81%	1°C	0%	3,70%	0%	
3	14:00	26°C	83%	26°C	82%	0°C	1%	0%	1,20%	
4	14:10	26°C	82%	26°C	82%	0°C	0%	0%	0%	

No.	Time	[1] *Thermo hygro*		[2] Monitoring Web		Difference		ΔX(%)		Status
		T	H	T	H	T	H	T	H	
5	14:20	27°C	78%	27°C	78%	0°C	0%	0%	0%	
6	14:30	27°C	78%	27°C	78%	0°C	0%	0%	0%	
7	14:40	28°C	78%	28°C	78%	0°C	0%	0%	0%	
8	**14:50**	**29°C**	**78%**	**29°C**	**78%**	**0°C**	**0%**	**0%**	**0%**	Selenoid On
9	15:00	27°C	86%	27°C	81%	0°C	5%	0%	5,81%	
10	15:10	28°C	79%	28°C	78%	0°C	1%	0%	1,26%	
11	**15:20**	**29°C**	**78%**	**29°C**	**77%**	**0°C**	**1%**	**0%**	**1,28%**	Selenoid On
12	15:30	26°C	85%	26°C	83%	0°C	2%	0%	2,35%	
13	15:40	27°C	81%	27°C	80%	0°C	1%	0%	1,23%	
14	15:50	28°C	80%	28°C	78%	0°C	2%	0%	2,50%	
15	**16:00**	**29°C**	**79%**	**29°C**	**79%**	**0°C**	**0%**	**0%**	**0%**	Selenoid On
16	**16:10**	**24°C**	**93%**	**24°C**	**93%**	**0°C**	**0%**	**0%**	**0%**	Fan On
17	16:20	25°C	89%	25°C	89%	0°C	0%	0%	0%	
18	16:30	26°C	86%	25°C	86%	1°C	0%	3,84%	0%	
				Average				**0,617%**	**0,798%**	

Description: T=Temperature. H=Humidity

The results of testing Table 1, which compares the measurements of the thermo hygro tool with the DHT11 sensor displayed by web monitoring in room A, obtained an average temperature data of 0.617%, the highest absolute error value at 16:30 with a value of 3.84% and an average humidity data of 0.798%, the highest total error value at 15:00 with a value of 5.81%.

Table 2. Testing Data for Room B

No.	Time	[1] *Thermo hygro*		[2] Monitoring Web		Difference		ΔX(%)		Status
		T	H	T	H	T	H	T	H	
1	13:40	28°C	86%	27°C	86%	1°C	0%	3,57%	0%	
2	13:50	28°C	86%	27°C	86%	1°C	0%	3,57%	0%	
3	14:00	27°C	85%	27°C	85%	0°C	0%	0%	0%	
4	14:10	27°C	85%	27°C	85%	0°C	0%	0%	0%	
5	14:20	27°C	85%	27°C	84%	0°C	1%	0%	1,17%	
6	14:30	28°C	82%	28°C	82%	0°C	0%	0%	0%	
7	14:40	29°C	81%	29°C	81%	0°C	0%	0%	0%	Selenoid On
8	14:50	27°C	85%	27°C	85%	0°C	0%	0%	0%	
9	15:00	28°C	83%	27°C	83%	1°C	0%	3,57%	0%	
10	15:10	28°C	83%	28°C	81%	0°C	2%	0%	2,40%	
11	15:20	29°C	81%	29°C	80%	0°C	1%	0%	1,23%	Selenoid On
12	15:30	27°C	86%	27°C	85%	0°C	1%	0%	1,16%	
13	15:40	27°C	83%	27°C	82%	0°C	1%	0%	1,20%	
14	15:50	28°C	81%	28°C	81%	0°C	0%	0%	0%	
15	16:00	29°C	80%	29°C	80%	0°C	0%	0%	0%	Selenoid On
16	16:10	24°C	95%	24°C	94%	0°C	1%	0%	1,05%	Fan On
17	16:20	25°C	93%	25°C	93%	0°C	0%	0%	0%	Fan On

No.	Time	[1] *Thermo hygro*		[2] Monitoring Web		Difference		$\Delta X(\%)$		Status
		T	H	T	H	T	H	T	H	
18	16:30	25°C	89%	25°C	89%	0°C	0%	0%	0%	
				Average				**0,595%**	**0,456%**	

Description: T=Temperature. H=Humidity

Table 3. Comparison of Room A and Room B

Room	%Error Temperature	%Error Humidity
Room A	0.617%	0,798%
Room B	0,595%	0,456%
Average %Error	0,606%	0,627%

Table 3 shows a comparison of the average absolute error in each room. Tests are carried out using the same tools and materials. Room B has a lower average fundamental error than Room A; this occurs due to differences in indoor conditions, such as the intensity of water in Room B affecting temperature and humidity. Based on the interpretation of the absolute error, the feasibility value is in the range of 0%-25% = success.

The success of system testing can be known through analytical calculations using the following equation 2.

$$P = \frac{F}{N} \times 100\% \tag{2}$$

P = Total percentage of success obtained
F = Frequency of success
N = Frequency Count
100% = Fixed number

Manual control testing on the website is done to determine if the control function can run well. Testing on manual control runs with good results, but there is often a delay when doing manual control. The research results can be seen in Table 4.

Table 4. Manual Website Control Testing

Room	Manual Control		Status
	FanDC	Selenoid	
Room A	On	Off	Success
	Off	On	Success
	On	On	Success
	Off	Off	Success
Room B	On	Off	Success
	Off	On	Success
	On	On	Success
	Off	Off	Success

Moreover, the Prototype testing is done by running the system prototype as a whole. This test will measure several functional parameters of the overall system prototype. The research results are as in Table 5.

Table 5. System Testing

No	Testing	Expectations	Conclusion
1	The sensor detects temperature >28°C	Automatic watering on	Success
2	The sensor detects temperature ≤28°C	Automatic watering is not on	Success
3	The sensor detects humidity >90%	*Fan DC* on	Success
4	The sensor detects humidity ≤90%	*Fan DC* does not turn on	Success
5	Login to website	Login Success	Success
6	Select the monitoring menu on the website	Display temperature and humidity data	Success
7	Manual watering on the website	Watering on	Success
8	Turning on the FanDC on the website	*Fan DC* on	Success

Based on Table 4 and Table 5, the total percentage of success obtained is:

$$P = \frac{16}{16} x 100\%$$

P = 100%

The overall system prototype test results are excellent. Automatic control and control on the website work well.

5. CONCLUSIONS

This research resulted in an absolute error average value for temperature data of 0.617% in room A and 0.595% in room B and an absolute error in humidity data of 0.798% in room A and 0.456% in room B. Based on the interpretation of the fundamental error, the feasibility value is in the range of 0%-25% = success. The automatic control is running well, as seen from the status in the table; the solenoid will turn on if the web monitoring shows a temperature >28°C, and the fan will turn on if it shows humidity >90%. The results for testing the overall system are excellent by getting an interpretation of the feasibility value of 100% (success).

AUTHOR CONTRIBUTIONS

Conceptualization; Abdul Wahid [A.W], Dimas Syahbani [D.S], Fhatiah Adiba [F.A], Methodology; [A.W],[D.S],[F.A], validation; [A.W],[D.S],[F.A], formal analysis; [A.W],[D.S],[F.A], investigation; [A.W],[D.S],[F.A], data curation; [A.W],[D.S],[F.A], writing—original draft preparation; [A.W],[D.S],[F.A], writing—review and editing; [A.W],[D.S],[F.A], visualization; [A.W],[D.S],[F.A], supervision project administration; [A.W],[D.S],[F.A], funding acquisition; [A.W],[D.S],[F.A], have read and agreed to the published version of the manuscript.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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