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IoT-Based Watering, Control, and Monitoring System for Tomato Plants Using Wemos D1 Mini

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Abstract. The growth of plant tomatoes is influenced by several factors, such as temperature, humidity, land, and rain. This study aimed to design the watering, control, and monitoring system for plants tomatoes with IoT-based using Wemos D1 Mini. The equipment is designed for sprinkling the plant tomatoes in a pot based on the response of a capacitive soil moisture sensor. The temperature was monitored using the DS18B20 sensor, and the presence of rain was determined using the raindrop sensor. On top of the equipment, an automatic on-off roof was built. This equipment was integrated with the website of Thingspeak and the Blynk application. The test results show that the design in this study could control the pump based on soil humidity with a control value of 60%. Furthermore, the built roof automatically works when detecting the temperature (higher or lower than 28°C) and the presence of rain.

Keyword: Capacitive Soil Moisture, DS18B20, IoT, Raindrop, Wemos D1 Mini

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1 Introduction

Tomatoes contain several benefits for the body. For example, vitamin C is used to strengthen the immune system and treat several diseases like cancer; vitamin A in tomatoes could treat and prevent xerophthalmia of the eye, and iron in tomatoes is beneficial for the formation of cell blood red. In addition, the fiber in tomatoes helps absorption and digestion of food, and tomatoes are also useful for lower blood tall because there is potassium in their content [1].

The ability of the tomato plant to produce fruits depends on genetics, the plant's growth, and the environment's condition. For example, tomato plants cannot withstand long-lasting rainfall because it will decrease growth; besides, it will cause tomato plants to be susceptible to disease. During the germination seeds process, the ideal temperature is 25-30°C, while for the growing process, the ideal temperature is 24-28°C [2]. The optimal humidity for growing tomato plants is 60% - 80%, so soil humidity is very important [3][4].

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Based on the above explanation, this study aimed to design the watering, control, and monitoring system for plants tomatoes with IoT-based using Wemos D1 Mini. The device in this design featured an automatic on-off roof that can be opened and closed based on the temperature and rain condition. Furthermore, this device also can monitor the temperature, soil humidity, and rain using the Thingspeak website and Blynk application [5][6].

2 Research Methodology

2.1 Block Diagram of The Device

The block diagram of the device is given in Figure 1.

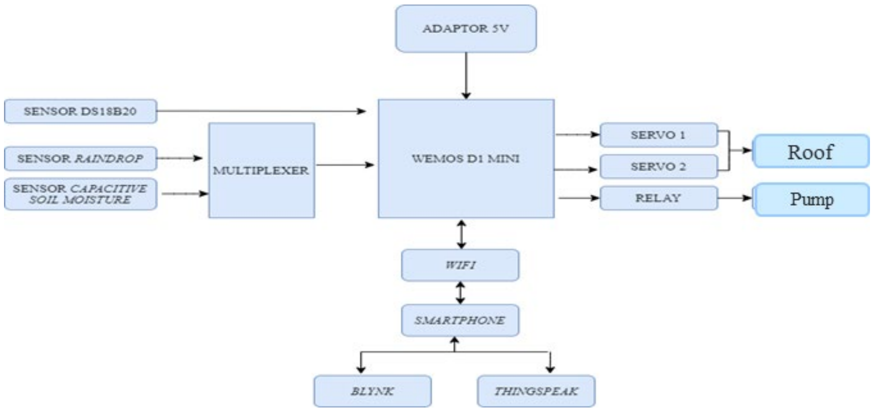

Figure 1. Block Diagram of The Device

2.2 The Electronic Circuit of The Device

The electronic circuit of the device is given in Figure 2.

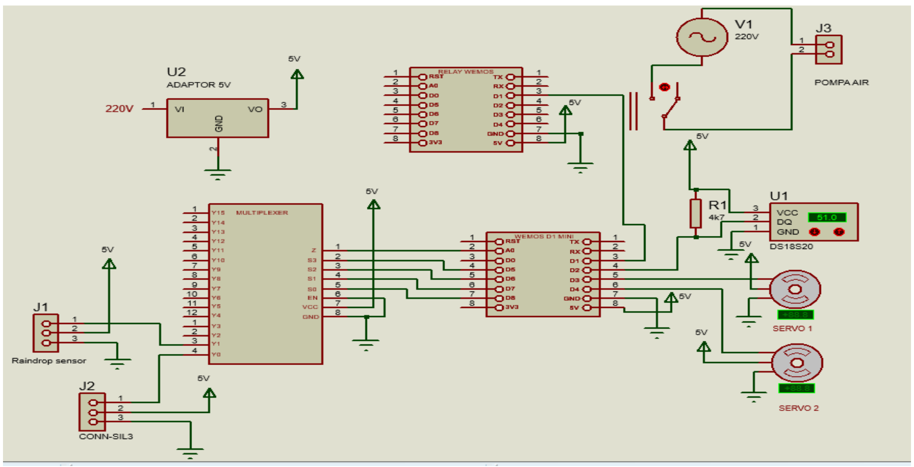

Figure 2. The Electronic Circuit of the Device

2.3 Calibration Techniques and Data Analysis

Calibration was conducted to achieve accurate measurement. In order to obtain the value of uncertainty, equation (1) was used to calculate the standard deviation [7].

$$D=\sqrt{\frac{\sum(x-\underline{x})^2}{n-1}} \tag{1}$$

Then, equation (2) was used to calculate the uncertainty (UA1)

$$UA_1 = \frac{\delta}{\sqrt{x}} \tag{2}$$

The third step is using equation (3) to find the uncertainty approach regression (UA2) value,

$$Y_{reg} = a + bx \tag{3}$$

where Y_{reg} is the equality regression value, variables a and b can be calculated using equations (4) and (5).

$$b = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2} \tag{4}$$

$$a = \underline{y} - b\underline{x} \tag{5}$$

The residual value sum square (SSR) is calculated using equation (6)

$$SSR = \sum (R)^2 \tag{6}$$

The uncertainty value from approach regression (UA2) is calculated using equation (7).

$$UA_2 = \sqrt{\frac{SSR}{n-2}} \tag{7}$$

2.4 Flowchart of The Device

Flowchart of the system is given in Figure 3.

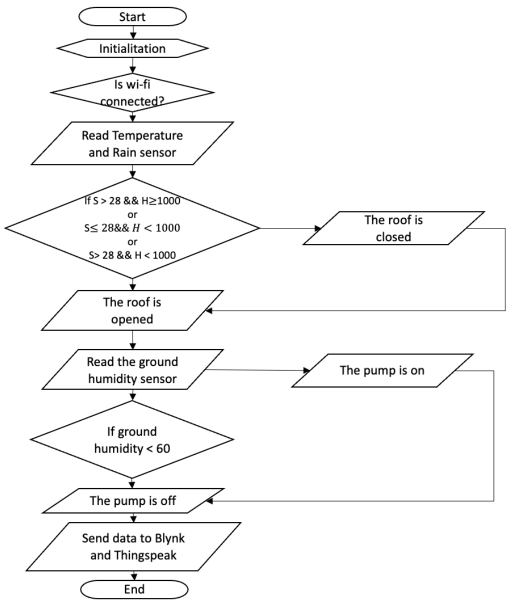

Figure 3. Flowchart of the Device

3 Result and Discussion

3.1 Raindrop Sensor Testing

A raindrop sensor works when there are water droplets on the sensor [8]. Table 1 shows the results of raindrop sensor data testing

Table 1. Raindrop Sensor data test results

Condition	Raindrop Sensor ADC Value	Roof
Not Raining	value >=1000	Open
Raining	Value <1000	Closed

3.2 DS18B20 Sensor Testing

The DS18B20 sensor is a digital temperature sensor with an output in the form of temperature data. The DS18B20 sensor requires a voltage from 3.0V to 5.5V power/data [9][10]. The comparison in this test is the HTC-1 digital thermometer. Table 2 and 3 are the results obtained in comparing the measurement results.

Table 2. DS18B20 Sensor Test Results With Comparison Thermometer

Test	Thermometer (HTC)	DS18B20 (X)	Difference (Y)	$(x-\overline{x})^2$
1	31.1 °C	31.5 °C	0.4	1.69
2	31.4 °C	32 °C	0.6	1.44
3	33 °C	33 °C	0	0.49
4	33.2 °C	33,5 °C	0.3	0.64
5	33.8 °C	34 °C	0.2	0.04
Average		32.8 °C	0.3	0.86
Value		164	1.5	4.3

Table 3. Calculated Standard Deviation of DS18B20 Sensor Measurement

XY	X^2	Y_{reg}	R	R^2
12.6	992.25	0.46	-0.06	0.0036
19.2	1024	0.4	0.2	0.04
0	1089	0.28	-0.28	0.0784
10.05	1122.25	0.22	0.08	0.0064
6.8	1156	0.16	0.04	0.0016
$\sum XY$ = 48.65	$\sum X^2$ =5383.75	$\sum Yreg$ =1.52	$\sum R$ = -0.02	$\sum R^2$ = 0.0004

Based on Tables 2 and 3, the standard deviation = $\sqrt{\frac{\sum(x-x)^2}{n-1}} = \sqrt{\frac{4{,}3}{4}} =$ 1.036. Uncertainty value $UA_1 = \frac{\delta}{\sqrt{n}} = \frac{1{,}036}{\sqrt{5}} =$ 0.463. Variable value = $b = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2} = \frac{-2.75}{22{,}75} =$ -0.12. Variable value = a = $\underline{y}$- $b\underline{x}$ = 0.3 – (-0, 12)(32.8) = 4.24. So, the regression Y_{reg} = + bx = 4.24 + (-0.12)x. The SSR = $\sum(R)^2$ = 0.0004. $UA_2 = \sqrt{\frac{SSR}{n-2}} =$ 0.011. The equality regression: b = $\frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2} = \frac{-2.75}{22{,}75}$-0.12. and a = $\frac{\sum Y \sum x^2 - \sum X \sum XY}{n\sum x^2 - (\sum x)^2} = \frac{97{,}025}{22{,}75} =$ 4.2, so y = a + bx = 4.2 + -0.12x. Correlation value thermometer with DS18B20 = r = $\frac{n\sum(XY) - \sum X \sum Y}{\sqrt{(n\sum X^2 - (\sum(X)^2(n\sum Y^2 - (\sum Y)^2)}} = \frac{24.25}{25.2} =$ 0.962. From Figure 8, the connection between Y_{reg} and the DS18B20 sensor is linear.

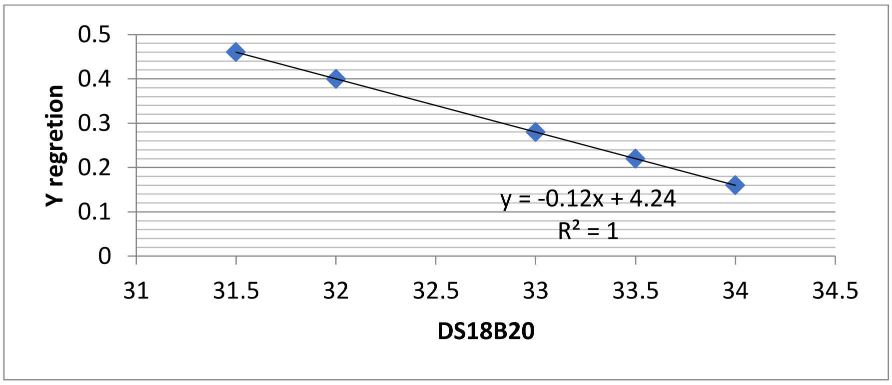

Figure 4. Graphics DS18B20 Sensor Testing

3.3 Capacitive Soil Moisture Sensor Testing

Capacitive Sensor Soil Moisture is a humidity sensor that can detect moisture in the soil. The voltage required for this sensor is from 3.3V to 5.5V power/data. The comparison used in the test is the Three-Way Meter brand of soil moisture measuring instrument. Tests were conducted on several times of experiment.

Table 4 Test Results of Capacitive Soil Moisture Sensor

Test	Measuring Tool (%)	*Capacitive Soil Moisture (%)* (X)	Difference (Y)	$(x-\overline{x})^2$
1	30	35	5	707.56
2	40	43	3	345.96
3	60	61	1	0.36
4	70	78	8	268.96
5	90	91	1	864.36
Average		61.6	3.6	437.44
Value		308	18	2187.2

Table 5 Calculation Results of Standard Deviation of Capacitive Soil Moisture Measurement

XY	X^2	Y_{reg}	R	R^2
175	1225	3,945	1.055	1.113025
129	1849	3,841	-0.841	0.707281
61	3721	3,607	-2,607	6.796449
624	6084	3,386	4,614	21,289
91	8281	3,217	-2,217	4.915089
$\sum XY$ = 1080	$\sum X^2 = {}^{21160}$	$\sum$Yreg =17,996	$\sum$R=0.004	$\sum R^2$ = 0.000016

Based on tables 4 and 5, the value of standard deviation = $\sqrt{\frac{\sum(x-\underline{x})^2}{n-1}} = \sqrt{\frac{2187{,}2}{4}} = 546.8$. Uncertainty value $UA_1 = \frac{\delta}{\sqrt{n}} = \frac{546{,}8}{\sqrt{5}} = 244.53$. Variable value = $b = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2} = \frac{-144}{10936} = -0.013$. Variable value = $a = \underline{y} - b\underline{x}$ = 3.6 – (- 0.013)(61.6) = 4.4. So, the regression Y_{reg} = + bx = 4.4 + (-0.013)x. Amount residue rank two $SSR = \sum(R)^2$ = 0.000016. $UA_2 = \sqrt{\frac{SSR}{n-2}} = 0.002$. Equality regression b = $\frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2} = \frac{-144}{10936} = -0.013$ and a = $\frac{\sum Y \sum x^2 - \sum X \sum XY}{n\sum x^2 - (\sum x)^2} = \frac{48240}{10936} = 4.4$, so y = a + bx = 4.4 + -0.013x. Correlation value = r = $\frac{n\sum(XY) - \sum X \sum Y}{\sqrt{(n\sum X^2 - (\sum(X)^2(n\sum Y^2 - (\sum Y)^2)}} = \frac{11080}{11165{,}58} = 0.992$. From Figure 5, The relation between Y_{reg} and the capacitive soil moisture sensor is linear.

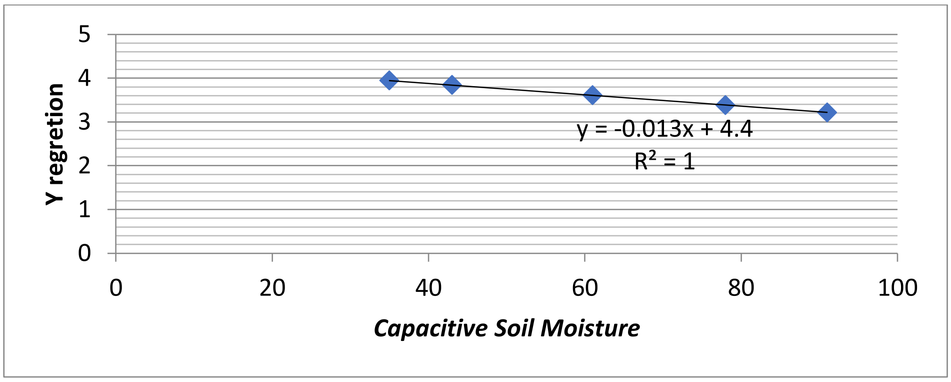

Figure 5. Graph of Capacitive Soil Moisture Sensor Testing

3.4 The Device Testing

The device testing was conducted by pairing the power supply to the circuit and then turning on Wi-Fi to connect the circuit to the internet. Then the system will read each program, firstly reading the temperature sensor, then the rain sensor where there is a command that if the temperature is > 28 degrees and the rain value is >= 1000, then the roof is closed; if the temperature is <= 28 degrees and the rain value is <1000 then the roof is closed, if the temperature is > 28 degrees and the rain value is <1000 then the roof is closed, and if the temperature is <=28 degrees and the rain value is >=1000 then the roof will be open. This system uses a servo to automatically open and close the roof, whereas the researcher uses two servos on the right and left of the roof so that the roof can open and close easily (Figure 6). Secondly, reading the capacitive soil moisture sensor where there is a command that if the humidity is <60%, then the relay will automatically turn on the water pump, and if the humidity is >= 60%, then the relay will automatically turn off the water pump. Users can monitor temperature, soil moisture, and rain conditions through smartphones, where users can monitor the system through Thingspeak and Blynk. At Thingspeak (Figure 7), users can monitor the system in the form of graphic data, and the user can save the graphic data. On Blynk, users can monitor the system using a gauge widget. In this application, there is a notification feature when the temperature is high (>28 °C), the temperature is not high (<=28 °C), rainy weather, the weather is not raining, and the user can see notifications from a smartphone (Figure 8). Table 6 shows the test results of the device.

Table 6. Test Results in The Device

Time	Temperature sensor DS18B20 °C	Raindrop Sensor ADC Value	Sensor Capacitive Soil Moisture *(%)*	Pump	Roof
06.00	27.5	1020	46	ON	OPEN
08.00	28	1022	65	OFF	OPEN
10.00	30	1016	62	OFF	CLOSED
12.00	32	1023	58	ON	CLOSED
14.00	30.5	1023	70	OFF	CLOSED
16.00	30	576	68	OFF	CLOSED
18.00	27	834	74	OFF	CLOSED

Figure 6. Display of The Device

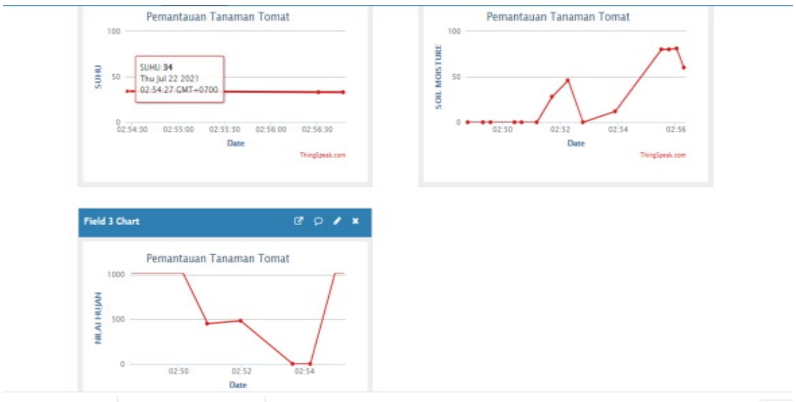

Figure 7. Display of Thingspeak Website

Figure 8. Display on The Blynk Application

4 Conclusion

The device for watering, controlling, and monitoring system for plants tomatoes with IoT-based using Wemos D1 Mini was successfully built. Based on DS18B20 sensor testing with the thermometer, the obtained equality regression is 4.2+(-0.12)*x*, and the correlation value is 0.962. Based on Capacitive Soil Moisture sensor testing, the equality regression is 4.4+(-0.013)*x,* and the correlation value is 0.992. Therefore, based on the device testing, it can work properly, suggesting using this device in real plantations.

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