Design of Internet of Things (IoT) based *Soil Moisture* Monitoring System Using Solar Power in Urban Agriculture (Horticulture)

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Abstract. Urban farming refers to cultivating plants around the urban environment by utilizing narrow or abandoned land in the house yard. The plants usually cultivated in urban agriculture are horticultural crops, such as lettuce. Agricultural irrigation accuracy is crucial, though it is often a hindrance because urban communities usually have other jobs besides farming and cannot constantly monitor their crops. Therefore, this study aimed to design a simple monitoring tool and make automatic irrigation systems that measure soil moisture, temperature, and water distance in reservoirs in urban agriculture. It used an Internet of Things (IoT)-based design developed using the Solar Cell as an energy source and could be monitored with a smartphone/PC. The system design uses soil moisture and temperature sensors, a mini water pump, and an ultrasonic sensor using the conductivity principle. The results indicated that the IoT-based monitoring device using solar power in urban agriculture was successfully designed using ESP-WROOM-32 displayed on the Blynk platform by testing the entire system.

Keywords: *ESP-WROOM-32, IoT, Soil Moisture, temperature, Solar Cell, Blynk,*

1. Introduction

Urban farming is a plant cultivation activity conducted around the urban environment using narrow or abandoned land in the house yard [1]. Success in agriculture depends on the water supply because plants naturally thrive with sufficient water availability. The control of regulating and providing water for plants is called irrigation. Furthermore, the irrigation system is where water is channelled into the soil to support plant growth and development [2]. In urban farming systems, people usually have other activities besides plant cultivation. The community has limited time to care for and monitor their plants [3]. Therefore, the accuracy of the irrigation system is often a problem, hindering optimal plant growth. As a solution to overcome these challenges, this study aimed to design Internet of Things (IoT)-based plant monitoring systems with automatic watering [4]. However, it did not explain the source of electrical energy used by the system and only focused on tomato plants.

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In this study, electrical energy was supplied by a battery integrated with Solar Cell. The renewable energy-based Solar Cell could charge batteries to power a water pump and become an energy source for the entire system. The tool could be designed to conduct automatic observations and control the crop irrigation system using the IoT platform, facilitating remote monitoring by urban farmers.

2. Design System

This research was conducted in Raja Ali Haji Maritime University Electrical Laboratory from September 2021 to July 2022. The system design is carried out in two stages, hardware design and software design. Hardware design is the design of electronic components that connected using cables so that they can work simultaneously. Hardware design has three important parts, input, process, and output. The main components in the hardware design are the YL-69 Soil Moisture sensor, the DHT11 sensor, the Ultrasonic sensor, the INA219 sensor which functions as input, the ESP-WROOM-32 microcontroller which functions as a process, Solar Cell and battery as a power source, and the MicroSD Card Module. which serves as an output for storing data on the MicroSD Card and the Blynk IoT platform for displaying data. The hardware design can be seen in Fig 1.

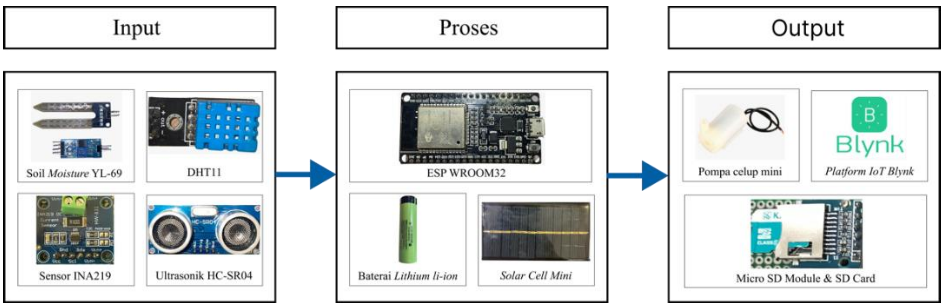

Figure 1

2.1 Data Processing and Analysis

The YL-69 Soil Moisture sensor, DHT11 sensor, Ultrasonic sensor, and INA219 sensor will first be calibrated to determine the accuracy of the sensor in reading data. Sensor calibration will be done by comparing the value on the sensor with the value on the calibrator. The values read by the sensor and calibrator will be compared using a linear regression equation to obtain calibration results [5]. The linear equation is as follows:

$$y = ax + b$$

Information:
y and x = Observation variables.

a and b = constant value.

After the results obtained from the comparison of the sensor and calibrator, then look for the value of the difference between the sensor reading value and the calibrator value. This difference value is used to determine the magnitude of the error from the sensor reading. Finding the error value can be seen in Equation below.

$$error = \left(\frac{calibration\ value - sensor\ value}{calibration\ value}\right)$$

After the error value is known, then look for the percentage of error value from sensor readings.

Finding the percentage error value can be seen in equation below.

$$\%\ \text{error} = \left(\frac{calibration\ value - sensor\ value}{calibration\ value}\right) \text{ x } 100\%$$

The next step to determine the level of accuracy and precision of the sensor will be calculating the error value using the Root Mean Square Error (RMSE) calculation method. Root Mean Square Error (RMSE) is the magnitude of the prediction error rate where the smaller the RMSE value obtained (close to 0), the more accurate the prediction results will be [6].

The RMSE value can be calculated by equation below.

$$RMSE = \sqrt{\frac{\sum(y_i - x_i)^2}{n}}$$

Where:

∑ : Overall Data
y_i. : Predicted Value
x_1 : Actual Value
n : Total Data

3. Experiment

3.1 Whole system test

The whole system was tested to determine whether it worked properly. The testing was performed at the Faculty of Electrical Engineering, Raja Ali Haji Maritime University, as shown in Figure 2. The results showed that the Soil Moisture 1 and 2 sensors could read soil moisture data. The DHT11, the HC-SR04 Ultrasonic, and the INA219 sensors could read air temperature around plants, water level, as well as Solar Cell voltage and current. The data obtained were stored in the MicroSD card shown in Figure 3 and sent to the Blynk IoT platform illustrated in Figure 4.

Figure 2

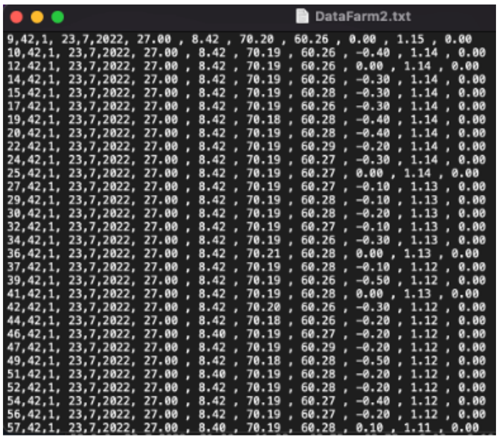
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Figure 3

Figure 3 shows the data on the MicroSD card when testing the entire system. The figure from left to right indicates the time, date, data from DHT11, Ultrasonic sensor, the Soil Moisture 1 and 2 Sensors, current, voltage, and power. This shows that the MicroSD card has stored data properly.

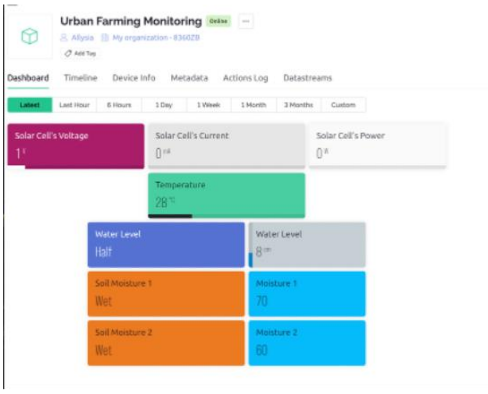

Figure 4

3.2 Field trial system

Field trials were conducted at the Faculty of Engineering, Raja Ali Haji Maritime University. The location of the field test can be seen in Figure 5.

Figure 5

Field tests were carried out to obtain monitoring data for soil moisture, voltage, current, and power on the Solar Cell, as well as water level monitoring data, and air temperature monitoring data around the plant. Monitoring data was obtained from the MicroSD card (Figure 6) and data platform Blynk (Figure 7).

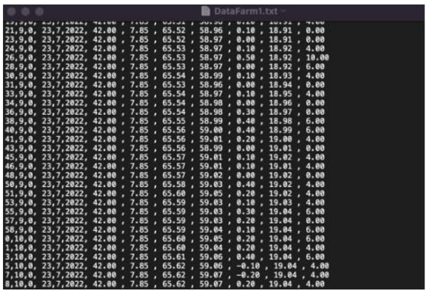

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Figure 6

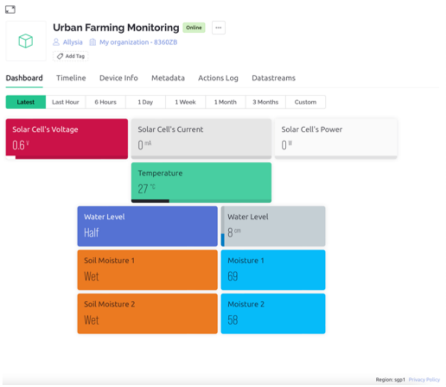

Figure 7

Figure 7 shows the overall view of the system contained in the display in Blynk. Screenshot of the display on the Blynk platform, is a screenshot of the field test after sunset. The results that can be seen in Figure 65 are the value of the solar cell voltage of 0.6 Volts, the current of 0 milliamperes and the Solar cell power of 0 watts. The temperature at the time of measurement was 27 degrees Celsius, the water level was 8 cm, Soil Moisture 1 was 69 and Soil Moisture 2 was 58. This is in accordance with the design where the value displayed on the dashboard is wet.

4. Result and Discussion

The YL-69 Soil Moisture Sensor reads soil moisture values accurately only when its placement is considered. This is because placing the sensor close to the water channel could result in non-uniform soil moisture values. The mini 5v dc water pump has a significant flow rate of 120 L/hour, and the sensor cannot detect the ideal soil value. The voltage absorbed by the Solar Cell has various values influenced by solar radiation and light intensities. When the sun is bright, the Solar Cell charges the battery using a charge controller. The system only works for 1 hour and 37 minutes after 6 pm.

Batteries are arranged in series to ensure the voltage value increases and turn on the charge controller. However, the series circuit overcharges and shortens battery life [7], damage minimized using Battery Management System (BMS). Blynk works effectively in displaying data and storing raw data. It is important to note that a poor internet network could cause delays in sending and reading fast-intensity data, resulting in significant packet loss [8].

5. Conclusion

This study designed an IoT-based monitoring system using solar power in urban horticulture agriculture. The results showed that the Soil Moisture sensor reads the dry soil moisture value as the Relay activates the pump. Furthermore, the ESP-WROOM-32 sends data to the Blynk IoT platform using the internet network. The difference in the data contained in the MicroSD card and Blynk raw data is caused by the influence of the internet network quality. The average accuracy of the Soil Moisture, Ultrasonic, and DHT11 sensor calibration is 98%, 96.71%, and 98% with an error percentage of 2%, 3.29%, and 2%, respectively.

Acknowledgements

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