

Internet of Things Based Intelligent Water Management System for Plants

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ABSTRACT

Water has an important role for crops. Every crop needs water to survive. The amount of water that crops need, in different regions and seasons, is different. To calculate the amount of water needed by the crop precisely require careful analysis of the available supporting data. In practice, the fulfilment of water needs in crops is only based on soil moisture without being adjusted to weather data. Thus, water is often wasted, for example when watering during high rainfall. Therefore, we need a system that can determine the volume of water requirements in crops based on its conditions, watering schedules, and weather data. This research aims to build a monitoring system for crops that can determine the right watering volume by considering soil moisture, air temperature and humidity, watering schedules, and weather data by utilizing the fuzzy method. Based on the results of our experiments, the system has managed to monitor crops and display watering volume notifications when its conditions are not normal and when to do watering based on the weather.

Keywords: smart water management, water monitoring, IoT, sensor, Fuzzy

1. INTRODUCTION

Water has a major role in the plant body. The role of water in the plant body includes: as a constituent of protoplasm, as a solvent for nutrients, as a substance that plays a direct role in metabolism, and also plays a role in cell enlargement and elongation. [1].

All crops need water to survive. The amount of water needed by different crops is not the same for different regions and seasons. To calculate and estimate how much water is needed by crops, careful and thorough analysis is needed of available supporting data such as climate data, irrigated area environment, crop types and cropping patterns, soil types, rainfall data, and other meteorological data [2].

Meanwhile, farmers still use manual methods in watering their crops, without considering some of the factors above. By using this manual method, water is often wasted or vice versa, water for crops is less. This is not good for crop growth, so it is necessary to develop a system that can calculate and provide the right amount of water for crops. To solve the problem of providing water for crops appropriately, several researchers have worked

in this field with various parameters, various approaches, various hardware, various platforms, and also utilizing analytical methods in it.

Vijay et. Al. [3] proposed intelligent agricultural monitoring and irrigation systems with ThingSpeak and NodeMCU based IoT platforms. This system monitors temperature and humidity to optimize water use. The data from the sensors is sent to the IoT platform, analyzed with Matlab to take appropriate action, and if the value is below the threshold, a notification will be sent to the user via email.

Chen Yuanyuan et. Al. [4] proposed intelligent water-saving irrigation based on ZigBee-wifi. The system monitors soil conditions based on soil moisture sensors using several sensors placed in certain planting areas. The results of soil moisture monitoring are used as a reference in making decisions about when to start and when to stop irrigation.

Maria Gemel et. Al. [5] proposed a water management system that utilizes temperature sensors, humidity sensors, and soil moisture sensors to collect data on crop and soil conditions. This data is then used to

determine the exact water requirements for tomatoes and eggplants. Overall this results in a total savings of 44% in water consumption, and the crops are visually healthier than traditional watering methods.

R. Kondaveti et. al [6] proposed an automatic irrigation system with precise rainfall prediction algorithms that can help us determine what crops are suitable for planting in a particular area. Automatic irrigation is used to water crops when needed by activating an electric motor, this can save water and electricity so it is very beneficial for farmers.

Jiaying Xie et al [7] conducted a study to predict the water requirement for longan garden irrigation based on three environmental factors: air temperature, soil moisture content, and light intensity. The data is then processed using the backpropagation neural network method using a genetic algorithm to optimize the weight and threshold of the artificial neural network. This model is used to predict irrigation water requirements based on environmental factors in longan plantations.

S. Kumar [8] proposed a lawn watering system using soil moisture sensors and weather forecast data. The soil moisture sensor is used to provide information on the water content in the soil, if the soil moisture is below a certain level the watering system will activate automatically. Weather forecast data is used to get rain information so that if there is a rain prediction, watering will be delayed by one to two days. Weather prediction data is obtained from the Indian government website <http://www.indiaweather.gov.in> which provides weather information for the next 6 days, as well as weather information for 24 hours.

Based on those research, we propose real-time water demand monitoring system for crops by combining sensor data (soil moisture, temperature and humidity), watering scheduling data and weather data to determine the volume of watering crops using fuzzy method.

2. PROPOSED SYSTEM DESIGN

The solution we propose aims to solve the problem of how to determine the right volume of watering crops based on its conditions, watering schedules and weather predictions with the required volume of water output. The proposed system consists of four important parts as shown in Figure 1 below.

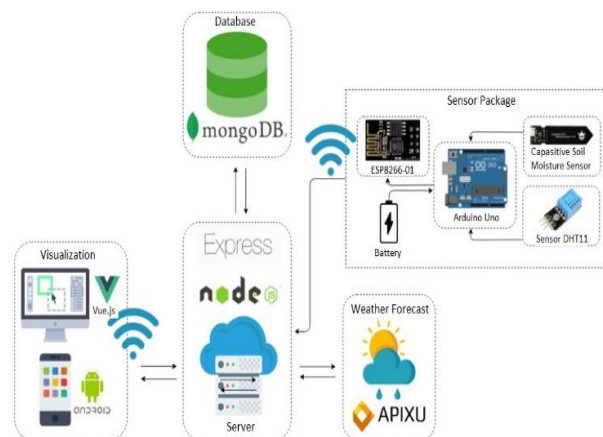


Figure 1 Proposed system design

The first part is a sensor system designed to monitor the state of soil moisture, air temperature, and air humidity in crops, which consists of a Capacitive Soil Moisture Sensor and a temperature and humidity sensor. (DHT11 sensor). The two sensors are connected to Arduino Uno to get soil moisture data, air temperature data, and air humidity data. The data is sent via the ESP8266-01 Wi-Fi module which is connected to the Arduino Uno to the second part (server) then processed using the fuzzy logic method to get the volume of water needed by the crops. The server requires weather data (part two) as well as the time and schedule for watering crops (part three) according to the type of crop to determine water requirements and watering times more accurately. The latest weather data is obtained through apixu.com api weather (third part) which is used to get a forecast of whether it will rain today or not. The results of processing on the server are displayed in the form of visualization of watering needs in the fourth part.

3. EXPERIMENTAL STUDY

In this system there are 3 fuzzy variables used in the fuzzification process, namely soil moisture, temperature and volume variables that will be used in decision making.

Soil moisture sensor is useful for observing the value of moisture in the soil. Soil moisture data is expressed in units of %RH. Soil moisture sensor data is divided into three categories, namely dry, moist, and wet. To provide a clear picture of the fuzzy set of soil moisture sensors, it can be described in the membership function shown in Figure 2.

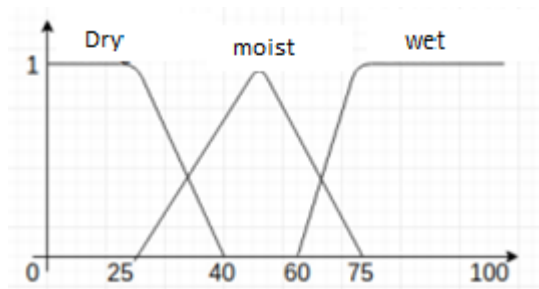


Figure 2 Fuzzy set of temperature variable (°C)

The temperature sensor is useful for observing the value of the air temperature around the monitored environment. The temperature sensor data is divided into five categories, namely cold, cold, normal, warm and hot. To provide a clear picture of the fuzzy set of temperature sensors, it can be described in the membership function shown in Figure 3.

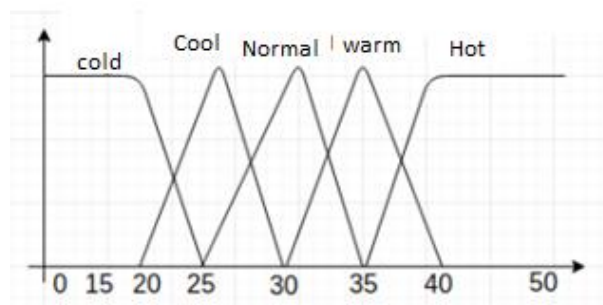


Figure 3. Fuzzy set of temperature variable (°C)

This volume set is the result set that is used to determine the final result of this fuzzy process.

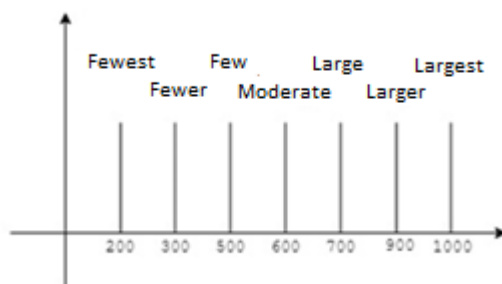


Figure 4. Fuzzy set of volume variable (mL)

After the fuzzification stage, fuzzy rules will be formed. The formation of fuzzy rules is done to express the relationship between input and output. The operator used to connect two inputs is the AND operator, while the operator that maps between input and output is IF-THEN.

This volume set is the result set that is used to determine the final result of this fuzzy process. The number of rules formed is obtained from the multiplication between each membership of the fuzzy variable. In this study, 15 rules were formed from the use

of 2 parameters. Examples of rules that have been formed can be seen in Table 1.

Table 1. Fuzzy Logic Rules

	Cold	Mild	Normal	Warm	Hot
Wet	Fewest	Fewer	Few	Moderate	Large
Moist	Fewer	Few	Moderate	Large	Larger
Dry	Few	Moderate	Large	Larger	Largest

After getting the rules used in the inference process, the next thing to do is to aggregate or combine the output of all the rules. This stage is called the Composition stage which will produce the predicate of each rule.

After going through the Composition stage which produces -predicate from each rule, the next step is the Defuzzification process. This defuzzification process is a crisp output calculation process by calculating the average of all z with the following formula:

$$z = \frac{\alpha_1 * z_1 + \alpha_2 * z_2 + \dots + \alpha_n * z_n}{z_1 + z_2 + \dots + z_n} \quad (1)$$

The following is an illustration of the stages of preparation for the trial environment that will be carried out. System testing should be carried out on agricultural land that has "bedengan" (part of the ground that is raised for plants to grow). "Bedengan" generally have a width of 100 cm with a length that is adapted to soil conditions. The height of the "bedengan" is approximately 20 cm with a distance between the "bedengan" of 100 cm. See figure 4 for the illustration of "bedengan".

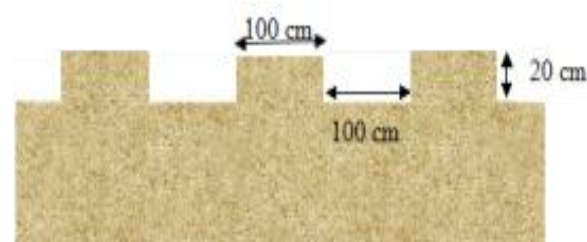


Figure 5 Overview of "bedengan" in general

Planting crops in "bedengan" has its own rules. One "bedengan" consists of 2 rows, and each row has a distance of 60-70 cm. And the distance between the crop holes is 60 cm. Figure 8 is a description of the system testing on a "bedengan" with a size of 1 m². This system should be tested on open agricultural land so that water and weather requirements can be tested in real time. However, due to time constraints, the trial was carried out on polybags with the same concept of "bedengan" and calculations. Tests on polybags can be seen in Figure 6,7 and Figure 8.

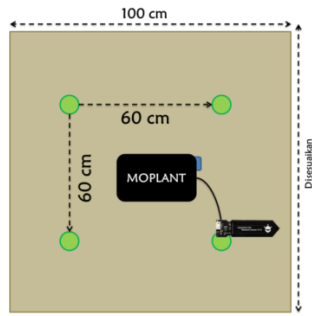


Figure 6 “Bedengan” in an area of 1 m²

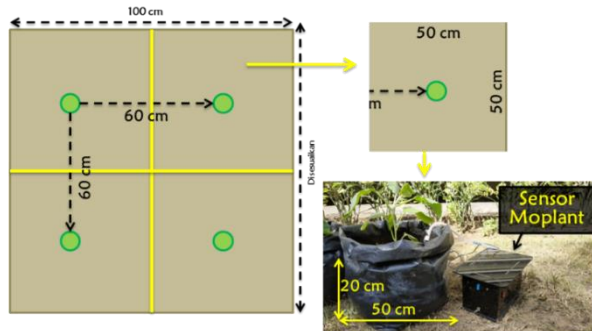


Figure 7. Transition of trials from agricultural land to polybags



Figure 8. Trial prototype

System testing was carried out on polybags with a height of 20 cm and an area of 50 cm x 50 cm. This concept is the same as the concept of beds on agricultural land. Crops are placed in open land and not indoors or in the shade. This experiment was carried out for 4 days. Watering is done twice a day if the weather on that day is sunny and the soil moisture value is less than the normal limit. Watering is done once a day if the rainfall is low on that day and the soil moisture value is less than the normal limit. Watering is not carried out if on that day the weather predicts high rainfall. The data for each scenario will be stored in a database that is useful for analyzing the results of system trials.

. Table 2 contains crop monitoring data carried out for 4 days for trials carried out on polybags. The parameters monitored were the value of soil moisture, air temperature, and air humidity taken before watering the crops. In table 2 it can be seen that the soil moisture value

is lower than the optimum soil moisture value for eggplant which should be in the range of 60% - 80%. The monitoring results also show that the temperature and humidity values are quite constant.

Table 2. Monitoring Before Watering

No	Date	Parameter		
		Soil Moisture	Air Temperature	Humidity
1	1 st day	28	31	75
2	2 nd day	39	31	76
3	3 rd day	45	32	77
4	4 th day	55	32	71

Table 3 shows the performance results of the system that has been created. On the first and second days there was no rain, so watering in the morning and evening was still carried out. Notifications have also worked according to the watering schedule based on weather conditions and crop conditions.

Table 3. Notifications based on existing conditions.

No	Date	Time	Total rainfall/day	Watering [Yes/No]	Volume [m ³]
1	1 st day	09.00	0 mm	Yes	940
2	2 nd day	17.00	0 mm	Yes	900
3	3 rd day	09.00	0 mm	Yes	500
4	4 th day	17.00	0 mm	Yes	400

Table 4. Monitoring after watering.

Date	Time	Watering Volume	Parameter		
			Soil Moisture	Air Temperature	Humidity
1 st day	09.00	940	90	32	72
2 nd day	17.00	900	97	32	73
3 rd day	09.00	500	70	32	73
4 th day	17.00	400	80	32	73

Table 4 contains data from the 2-day trial. In this table there is a date column that shows when the experiment was carried out, a watering time column, and a watering volume column. There is also a column of soil moisture, air temperature and humidity that contains the data values measured after watering.

There are two application interfaces for this system, web-based and android-based. The interface of this application can be used to monitor the condition of the

crop and display the amount of water it needs. Web-based applications are used to determine crop conditions in detail, making it easier for farmers to take an action. There is a graph that displays the condition of the last 100 data. The android application is used to make it easier for farmers to monitor their crops at any time, and provide notifications if there is a need for watering for crops. The interfaces of these two applications can be seen in Figures 9 and 10.



Figure 9. Web application interface

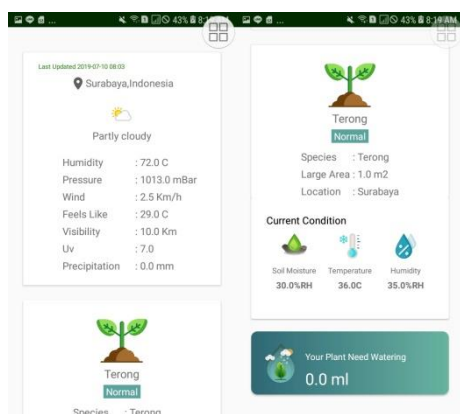


Figure 10. Android application interface

4. DISCUSSION AND CONCLUSION

On the first day of the experiment, it was used to see the condition of the crops, where the crops were not in accordance with the ideal conditions, the crops gradually reached the ideal conditions after the fourth day. Experiments were carried out on eggplant crops. In general, eggplant crops have an optimum humidity value of 60% RH - 80% RH. So that on the fourth day of the experiment the volume calculation was appropriate because after giving the volume the value of soil moisture was between the values of 60% RH - 80% RH.

Implementation of crop condition monitoring on the device can work in real-time. After conducting several trials on the actual crop environment, it can be concluded that this application has succeeded in monitoring crops and displaying watering volume notifications when crop conditions are not normal or when the time for watering crops based on the weather has arrived.

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