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Weather Prediction Based on Fuzzy Logic Algorithm for Supporting General Farming Automation System

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***Abstract*—Many automation and monitoring systems in agriculture do not have a calculation system for watering based on weather. Of these issues, will be discussed weather prediction system using fuzzy logic algorithm for supporting General Farming Automation. The weather calculation system works by taking a weather prediction data from the Weather Service Provider (WSP). Furthermore, it also retrieves soil moisture sensor value and rainfall sensor value. After that, the system will calculate using fuzzy logic algorithm whether the plant should be watered or not. The weather calculation system will help the performance of the General Farming Automation Control System in order to work automatically. So, the plants still obtain water and nutrients intake are not excessive.**

Keywords: Watering, Weather, Weather Service Provider, Fuzzy Logic, General Farming Automation

I. Introduction

Indonesia is an agricultural country because the majority of the Indonesian population livelihood depends on agricultural sector or farming. Indonesia was ranked 71 out of 113 countries on the International food security in 2016 ~~was~~ released by The Economist Intelligence Unit [1]. From these results, it appears that Indonesia has increased from the previous year, although still rated low. So, Indonesia desperately needs the latest innovations to assist residents in farming.

Many farming methods have been developed to improve the quality of agricultural production. One of them is the hydroponic growing methods, this is a method of farming with water as medium and the nutrients dissolved in the water. This hydroponic method is suitable to use in places where farmland area has begun to decrease and soil conditions ~~that~~ are no longer fertile [2]. In addition, there are also methods of aeroponics. This method uses air as a medium in agriculture. It works by using ~~a~~ mist or droplets ~~made~~ of water and liquid nutrients which is sprayed onto the plant's roots. Aeroponics method can reduce water use by 98% compared with hydroponics, reducing the use of fertilizers to 60% and can increase production up to 45% to 75% [3]. There is also a method of aquaponics. This method can be combined with fish farming, where the source of nutrients can be taken from the fish pond. This method can also be combined with a hydroponic system by using continuous water flow without the need to use any soil [4].

There are so many methods that can be used in farming. Even with advances in technology, there are a lot of automation systems and monitoring systems to help agriculture, one example is the nutrient or fertilizer control in the hydroponic system. The device used is the PSoC4 ARM Cortex-M0, Relay, Water Pump, Pump Nutrient and LCD. Where the system will perform a routine fertilizing every week based on a timer. Fertilization is done by mixing the water and the nutrients, then supplied it to the root of the plant. This technique, can increase plant growth between 40-50% compared with soil method [5]. In addition, the system also is an example of the control system and monitoring system applied to the aeroponics method. This system can help in monitoring the state of the water and the light intensity around the plants displayed in a web. The system has a pH sensor, temperature sensor, and light sensor. There is also a mist maker to produce a mist of water mixed with nutrients. The system works by blowing mist towards the plant roots for 5 minutes then the system will stop blowing the mist for 15 minutes, and so on. Besides the mist blowing system there is also a monitoring system used to monitor the state of temperature, pH and light intensity. Sensor data are sent via the internet using GSM / GPRS module and stored into the data center platform for IOT (Internet of Things) [6]. This system uses solar panels as power source. This system aims to save electricity so that harness the sun's energy resources. This system requires a battery for storage of electrical energy, so that the system can still work at night. In this system, there is also a DC to AC converter to convert direct current into alternating current [7].

Most of the automation system was created to focus in

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managing irrigation / watering the plants because the water is very important for the sustainability of living beings in the world. Therefore, there is need for a balance between the need and availability of water, including the water needs in the agricultural sector [8]. The water requirement of each plant is different according to the type of plant and its growth phase. In the dry season, the plants often get water stress because of shortage of water supply in the roots of plants. In the rainy season, plants often get water saturated conditions [9].The water content in the soil is always different because it is influenced by weather and climate. Climate and weather is what will affect the growth and productivity of plants. An example of the influence of weather and climate is shown in TABLE I.

TABLE I. DATA ELEMENTS OF WEATHER AND CHILI PRODUCTION IN SUMENEP [10]

Years	Rainfall per month												Temp	Rh	Production of Chilli
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1998	81	149	168	136	0	87	182	0	18	109	161	71	27.8	98.2	2509.75
1999	161	83	244	111	0	0	0	0	0	68	298	112	28	98.8	3006.51
2000	203	259	194	207	198	123	7	0	0	143	549	95	28.4	98.5	3503.27
2001	111	206	114	279	22	95	0	0	0	162	79	130	27.7	98.4	4067
2002	231	246	200	293	29	3	0	0	0	0	29	299	27.6	97.5	4169.26
2003	182	186	150	68	226	0	0	0	0	0	258	270	27.8	96.9	4598.22
2004	233	210	395	7	87	49	0	0	0	0	210	273	27.8	96.6	5646.42
2005	133	98	161	119	65	5	10	7	0	83	59	308	31.3	84.9	8332.33
2006	215	171	113	271	204	5	0	0	0	0	0	204	32.3	86.3	8332.58
2007	1690	2385	2384	1310	562	785	195	10	0	20	485	2895	32.3	92.1	8332.33

From the data above, it can be seen the results of the regression is Y = 10 567 + 3.90 (X1) - 0.012 (X2) - 0.078 (X3). The coefficient of determination (R2) is 0.82 or 82%. This situation shows that the influence of the independent variables (weather elements) on the dependent variable (production) is 82%. While 18% of the productivity of chili affected by other independent variables [10]. Of the importance of the weather elements, there is a control system that can help keep water in the soil. The system is used to perform plants watering and can be controlled from android application. The system uses Raspberry pi as a controlling device. The system will drain the water for 1 to 2 seconds if the water content in the soil has been reduced. The system is trying to maintain stability in the water or moisture content of the soil [11].

This paper presents an alternative method for plants watering based on weather prediction. The rest of this paper is organized as follows. In section II, we proposed the system design of weather prediction based on fuzzy logic algorithm. In section III, we present a result and discussion. Finally, the conclusion of this work is given in section IV.

II. PROPOSED WEATHER CALCULATION

A. System Design

As shown in Fig.1, the general concept of weather calculation for General Farming Automation is retrieving data of sensors and forecast from weather service provider, the system will calculate whether the plant should be watered or not using fuzzy logic algorithms.

B. Sensors System

There are two sensors on the General Farming Automation. In Fig. 2 is the Soil Moisture Sensor to determine rank of wetness of soil around the plant.

The sensors are an analog sensor, so the sensors required analog to digital converter to convert analog signals into digital signals. In Fig. 4 is a schematic of sensors with analog to digital converter module.

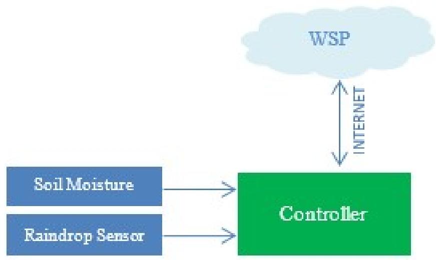

Fig. 1. System design.

Fig. 2. Soil Moisture Sensor [12].

Rain sensors to know the weather conditions around the plant are shown in Fig. 3.

Fig. 3. Raindrop Sensor [13].

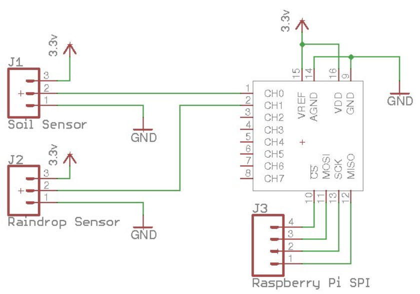

Fig. 4. Sensor system schematic.

From Fig. 4, the output of the sensor is input to the ADC module and the results are sent using the SPI to the controller.

C. Weather Service Provider

Weather Service Provider (WSP) used is Open Weather and Wunderground. Both of these providers provide Rest API weather prediction. Response from the WSP data in JSON format making it easier to process the data. Response from WSP is shown in Fig. 5.

D. Fuzzy Logic

Fuzzy Logic algorithm used to determine the eligibility of plants to be watered. In Fig. 6 is shown a diagram process of fuzzy logic algorithm.

The fuzzy logic calculation use four parameters as variables. That is value of soil moisture sensor, rain sensor, weather predictions from WSP Open Weather, and weather predictions from Wunderground. The fuzzy logic algorithm determined linguistic value of each variable. The fuzzification module will map the numeric value to fuzzy sets. Input value will be converted into input fuzzy as linguistic value. Fig. 7 shows a membership function of the fuzzy input from soil moisture sensor parameter.

```
{
  "response": {
    "version": "0.1",
    "termsofService": "http://www.wunderground.com/weather/api/d/terms.html",
    "features": {
      "conditions": 1
    },
    "results": [
      {
        "name": "Bandung",
        "city": "Bandung",
        "state": "BT",
        "country": "ID",
        "country_iso3166": "ID",
        "country_name": "Indonesia",
        "zmw": "00000.221.96737",
        "l": "/q/zmw:00000.221.96737"
      },
      {},
      {},
      {},
      {},
      {}
    ]
  }
}
```


Fig. 5. Example of response from WSP.

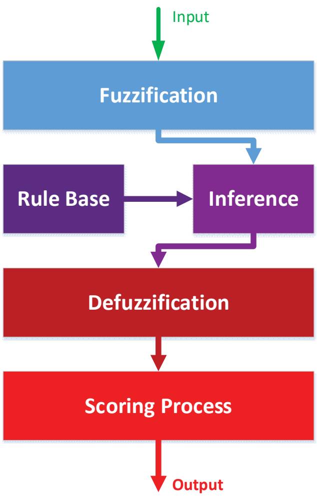

Fig. 6. Fuzzy process.

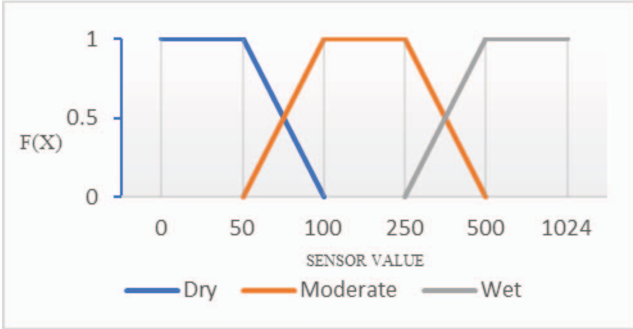

Fig. 7. Member function graphic of soil moisture sensor.

From the member function graphic of soil moisture sensor (Fig. 7) a formula to determine the value of linguistics. Soil moisture sensor has the linguistic form of dry, moderate and wet.

$$dry(x) = \begin{cases} 1, & x \leq 50 \\ \dfrac{100 - x}{100 - 50}, & 50 < x < 100 \\ 0, & x \geq 100 \end{cases} \quad (1)$$

$$moderate(x) = \begin{cases} 0, & x \leq 50, x \geq 500 \\ \dfrac{x - 50}{100 - 50}, & 50 < x < 100 \\ \dfrac{500 - x}{500 - 250}, & 250 < x < 500 \\ 1, & 100 \leq x \leq 250 \end{cases} \quad (2)$$

$$wet(x) = \begin{cases} 0, & x \leq 250 \\ \dfrac{x - 250}{500 - 250}, & 250 < x < 500 \\ 1, & x \geq 500 \end{cases} \quad (3)$$

In Fig. 8 is a membership function of the fuzzy input from raindrops sensor parameter.

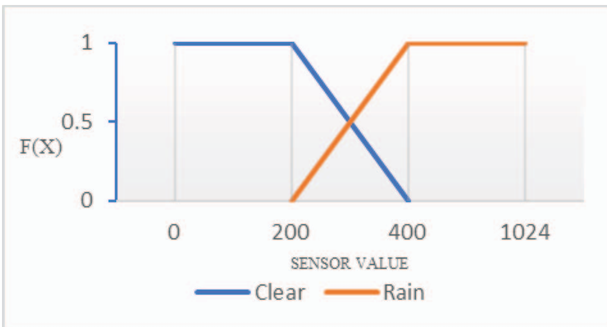

Fig. 8. Member function graphic of raindrops sensor

From Member function graphic of raindrops sensor (Fig. 8) can be written formula to determine the value of linguistics. Rain drops sensor has the linguistic form of clear, rain.

$$clear(x) = \begin{cases} 1, & x \leq 200 \\ \frac{400 - x}{400 - 200}, & 200 < x < 400 \\ 0, & x \geq 400 \end{cases} \quad (4)$$

$$rain(x) = \begin{cases} 0, & x \leq 200 \\ \frac{x - 400}{400 - 200}, & 200 < x < 400 \\ 1, & x \geq 400 \end{cases} \quad (5)$$

TABLE II shows the group and value of weather condition. Weather condition has been obtained from Weather Service Provider. From group and value of weather condition, forecast variable has linguistic form of clear sky, cloudy, rainy.

Fig. 9 shows membership function of weather prediction from open weather and underground. From member function graphic of weather prediction (Fig. 9) can be written formula to determine the value of linguistics.

TABLE II. GROUP AND VALUE OF WEATHER CONDITION

Weather Condition	Group of Condition	Value
Clear Sky	Clear Sky	0
Few Clouds	Cloudy	1
Broken Clouds		
Overcast Clouds		
light rain	Rainy	2
moderate rain		
heavy intensity rain		
very heavy rain		
extreme rain		
freezing rain		
light intensity shower rain		
shower rain		
heavy intensity shower rain		
ragged shower rain		

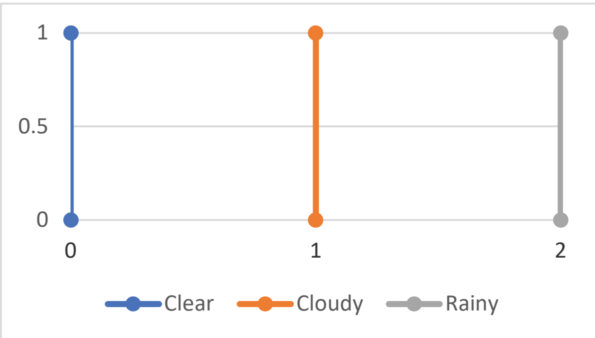

Fig. 9. Member function graphic of weather prediction

Weather prediction from openweather has the linguistic form of clear, cloudy and rainy.

$$clear(x) = \begin{cases} 1, & x = 0 \\ 0, & x \neq 0 \end{cases} \quad (6)$$

$$cloudy(x) = \begin{cases} 1, & x = 1 \\ 0, & x \neq 1 \end{cases} \quad (7)$$

$$rainy(x) = \begin{cases} 1, & x = 2 \\ 0, & x \neq 2 \end{cases} \quad (8)$$

Furthermore, Weather prediction from wunderground has the linguistic form of clear, cloudy and rainy.

$$clear(x) = \begin{cases} 1, & x = 0 \\ 0, & x \neq 0 \end{cases} \quad (9)$$

$$cloudy(x) = \begin{cases} 1, & x = 1 \\ 0, & x \neq 1 \end{cases} \quad (10)$$

$$rainy(x) = \begin{cases} 1, & x = 2 \\ 0, & x \neq 2 \end{cases} \quad (11)$$

After the fuzzification process, then continue to inference process. In the inference module simulated decision-making based on the fuzzy concept using the rules of knowledge. The fuzzy rule can be determined by combining all the linguistic of all variable. Output from inference process is eligibility value. We have 54 fuzzy rule based on combination of linguistic variables and knowledge about agricultural. Samples of fuzzy rule using if-then statement with AND operator are:

IF soil = dry AND raindrop = clear AND forecast1 = rainy AND forecast2 = rainy then high.
IF soil = wet AND raindrop = clear AND forecast1 = rainy AND forecast2 = rainy then low.
IF soil = wet AND raindrop = rain AND forecast1 = rainy AND forecast2 = cloudy then low

After inference process, next is defuzzification process using Centroid Method (Center of Gravity). The formula of Centroid Method is:

$$y* = \frac{\sum y\mu_R(y)}{\sum y\mu_R(y)} \quad (12)$$

A set of sample points needs to be taken to use the equation. The more samples taken, the results will be more accurate.

III. RESULT AND DISCUSSION

After implementation, a test is conducted to test functionality of the system's components.

A. Soil Moisture Sensor Test Result

The result from soil moisture sensor experiment indicates whether the soil conditions are wet or dry (TABLE III). The range value of soil moisture sensor is 0 – 1024. The sensor value is a digital value from ADC module.

TABLE III. SOIL MOISTURE SENSOR TEST RESULT

Soil Condition	**Digital Value**	**Analog Value (volt)**
dry	$1_{(10)} - 78_{(10)}$	2.11 – 2.54
moderate	$221_{(10)} - 389_{(10)}$	1.56 – 2.01
wet	$430_{(10)} - 890_{(10)}$	0.98 – 1.47

B. Raindrops Sensor Test Result

The output value from raindrops sensor is digital value from ADC (Analog to Digital Converter). This sensor indicates whether today is going to be raining or not (TABLE IV).

TABLE IV. RAINDROPS SENSOR TEST RESULT

Weather Condition	**Digital Value**	**Analog Value (volt)**
clear sky	$1_{(10)} - 17_{(10)}$	2.4 – 2.5
drizzle	$220_{(10)} - 360_{(10)}$	2.36 – 1.87
rain	$437_{(10)} - 765_{(10)}$	1.48 – 1.68

C. Fuzzy Logic Test Result

This test was conducted to determine the results of the calculation algorithm using fuzzy logic. In this case the value of soil moisture sensor is 441, the value of raindrop sensor is 1, weather prediction from Openweather is rain, and weather prediction from Wunderground is cloudy. Firstly, the fuzzification module maps numeric value into fuzzy set or fuzzy input (Figs. 10-11).

Fuzzy inputs of soil moisture sensor are moderate (0.236) and wet (0.764). Fuzzy input of raindrops sensor is clear (1). Fuzzy input of forecast-1 is rain (1). Fuzzy input of forecast-2 is cloudy (1). After that, in the inference process, system is simulated for decision-making based on fuzzy rule. So, it has been in accordance with the following rules:

IF moderate (0.236) AND clear (1) AND rain (1) AND cloudy (1) THEN high (0.236)

IF wet (0.764) AND clear (1) AND rain (1) AND cloudy (1) THEN low (0.764)

So, the outputs of inference process are high (0.236) and low (0.764), see Fig. 12. Based on these values, the defuzzification process determines feasibility value of watering the plants.

The defuzzification process used centroid method (center of gravity). The output of defuzzification is used as the eligibility value for watering plants. In this case, the eligibility value is 41.6831567. So, the plant should not be watered. In another test, we provide different conditions with several times of testing as indicated in TABLE V.

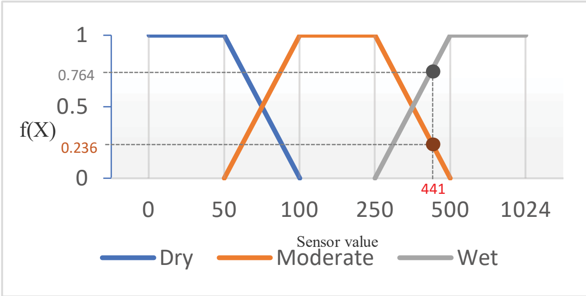

Fig. 10 Graph of soil moisture sensor value.

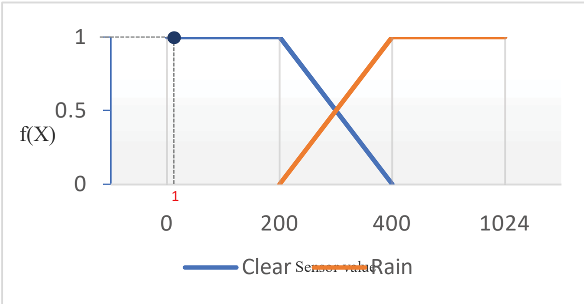

Fig. 11 Graph of raindrops sensor value.

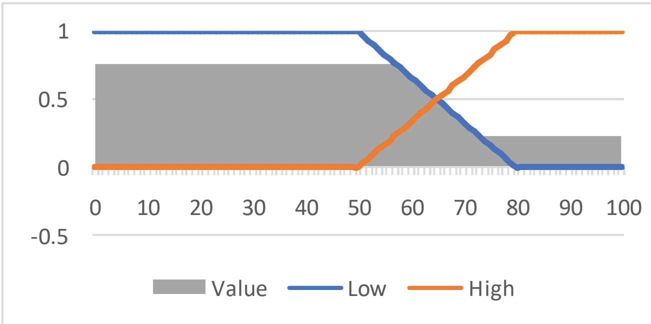

Fig.12. Fuzzy output value.

TABLE V. ANOTHER CASE AND RESULT OF FUZZY LOGIC TEST

Parameter	**Input**	**Linguistic**
Soil	389	Moderate (0,74) Wet (0.26)
Raindrop	1	Not rain (1)
Forecast 1	Cloudy	Cloudy (1)
Forecast 2	Cloudy	Cloudy (1)
Rule	**Feasibility Value**	**Decision**
Rule 23: High (0.74) Rule 41: Low (0.26)	65.1666666667	Need Watering

We have done the test up to 30 times with result 100% accuracy of fuzzy rule base.

D. The Whole System Test Result

Testing the whole system is done by planting plants and then observing it everyday (TABLE VI). The analysis is done by observing the system whether there is error system or not. The success rate of this test can be determined by the success of the system in treating the plant. We have done the test up to 33 times in 18 days with result 100% accuracy decision based on fuzzy logic algorithm.

TABLE VI. RESULT OF THE WHOLE SYSTEM

Time	Decision	Fertilization	Expectation	Status
6/5/2017 17:40	Not watered	Nurtured	Not watered & nurtured	Success
6/5/2017 5:54	Not watered	Nurtured	Not watered & nurtured	Success
6/4/2017 17:40	Not watered	Nurtured	Not watered & nurtured	Success
6/4/2017 5:54	Not watered	Nurtured	Not watered & nurtured	Success
6/3/2017 17:39	Not watered	Nurtured	Not watered & nurtured	Success
6/3/2017 5:53	Not watered	Nurtured	Not watered & nurtured	Success
6/2/2017 17:39	Not watered	Nurtured	Not watered & nurtured	Success
6/2/2017 5:53	Not watered	Nurtured	Not watered & nurtured	Success

IV. CONCLUSION

This paper successfully presented an alternative method for plants watering. Firstly, the system can retrieve sensor value and weather prediction data from cloud. Secondly, the system can determine the feasibility of watering plants based on fuzzy algorithm. Thirdly, the method can support General Farming Automation System. Future research on this field should be added calculations to fertilize plants.

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