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Automatic Watering Systems in Vertical Farming Using the Adaline Algorithm

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ABSTRACT

This paper proposes a vertical farming model, by producing multi-layered plants that are stacked vertically. The research approach was carried out to obtain the technology used to achieve the goal of providing land at low cost, by utilizing the Internet of Things (IoT). The process of watering plants is transformed into an automation process with a sprinkler that adjusts to the calibration temperature, air humidity, and soil moisture value. The stages of implementation in this study will be directed to two processes, namely the data preprocessing stage and the Adaptive Neural Network training process. The Adaline algorithm will determine the duration of the automatic watering can be divided into two, namely the training process and the testing process. Process inputs and targets are trained with a network that has been built to add weight to learning then used based on incoming data training which is then used to facilitate the beginning or end of automation time and then this feature is used to determine the exact time the automation process is created effectively. Information about temperature, humidity, soil moisture, and when the sprinklers are activated can be monitored online via the internet with an application integrated with the IoT (Internet of Things) database. The application of Artificial Neural Networks (ANN), especially the Adaline algorithm, requires a knowledge base to be created using temperature, humidity, and soil parameters as parameters to determine the duration of automation. Watering duration is grouped into 3 types, namely short (5 seconds), long (10 seconds), and off (0 seconds). This knowledge base is also followed by the target value, plus input data that can be observed first which is then processed using normalization techniques, then the data with the Adaline concept can be implemented in an automatic watering system on vertical land. The test results obtained from the Adaline algorithm on an automatic watering tool obtained an accuracy value of 91.7% precision test results, then through the Mean Absolute Error Percentage (MAPE) validation test, an error value of 8.3% was obtained.

***Keywords**: Automatic Watering, Adaline Algorithm, IoT, Vertical Farming*

1. INTRODUCTION

This research was conducted to improve the watering process in a limited vertical farming model at the right time. Over time, there has been a decrease in the area of agricultural land use from year to year, especially in big cities where land has been converted into social facilities which can result in a decrease in agricultural production. The impact of subsidence can be mitigated by farming techniques vertically using upward soil [1]. The proposed plant watering process is an automation process with an intelligent sprinkler system that adjusts to the values of temperature, air humidity, and soil moisture [2]. The focus in vertical farming is on the watering process. So far, the watering system in vertical plants has implemented an automation system, but this automation only depends on a predetermined time [3] [2], [4] - [8]. This has not been able to maximize the watering process due to different plant conditions and seen from the current routine of urban communities, continuous watering is difficult. This work is carried out using a microcontroller and sensors that will retrieve temperature, humidity, and soil moisture data on vertical farms. The results of sensor readings are processed using an artificial neural network algorithm, namely the Adaline Algorithm [9] [10] [11] - [14]. This algorithm can produce an output value between 0 to 1 which will activate the water pump automatically [15]. As well as vertical plant owners can monitor the watering process via the Android interface, so that vertical plant care can be monitored anywhere and anytime as long as it is connected to the internet network [2], [6], [16], [17].

1.1. Related Work

Previous research has been carried out by producing prototypes for monitoring and controlling water as well as fertilizing banana trees [18]. While the research was carried out by making a prototype of automatic watering using the FPGA Board [19]. Research to reduce manual labor and save labor time through the creation of automated systems to help increase agricultural or marine cultivation growth [20]. This automatic fish feed feeder system is implemented using 3 main components, namely Arduino, stepper motor, and stepper motor driver [20]. The working model principle is based on controlling the amount of food that is put into the fish tank unit at different time intervals. Another study aims to present an automatic water level control system to help users manage their water needs with a city water supply system. SMS notification is added to the automatic control system so that water can be managed by the user when a load shedding occurs [21] [22] [1]. The proposed method for monitoring voltage noise is better than conventional methods. In this study, the proposed method to monitor, detect and classify voltage disturbances is a combination of the Discrete Wavelet Transform (DWT) method and the Adaptive Linear Neural Network (Adaline) method [23] [24] [25]. DWT is used to detect the start/end time of voltage disturbances, then this feature is used to determine the exact time of the voltage disturbance. Then Adaline is used to estimating the typical characteristics of the voltage noise such as the magnitude of the voltage and the phase angle of the fundamental frequency component of the voltage noise signal [26]. One method that can be applied is a neural network algorithm that can generate rules from multiple inputs and make predictions about the possible outputs that will appear [9] [14] [15] [27]. Adaline is a two-layer neural network consisting of an input layer and an output layer. Research by applying the well-known training algorithm, Least Mean Square (LMS). It can estimate functions which have a linear input-output relationship and can work well even with some non-linear real-world applications [25].

2. METHODOLOGY

The system to be created in this study is briefly described through a scheme to find out how the whole circuit works so that a system that can be functioned and can work according to design will be produced.

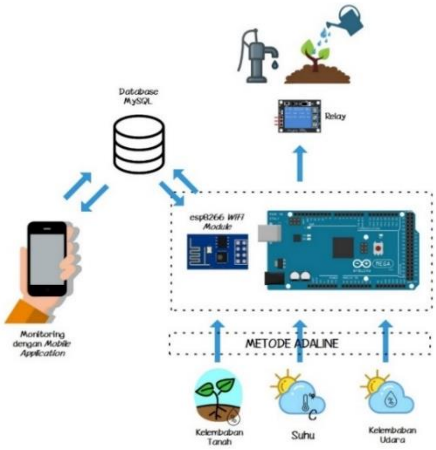

Figure 1 Schematic of the Proposed System.

From Figure 1, it can be seen that the system is designed using the Arduino Mega 2560 microcontroller as a microcontroller that will receive data input from the DHT11 sensor and YL-69 Soil Moisture Sensor. The data from the sensor is then processed using the Adaline algorithm and the results of the data processing will activate the water pump with a predetermined duration. The results of the data processing are then sent via the ESP8266 WiFi Module and can be accessed through an integrated Android-based application via a web server.

These data requirements include data on temperature, air humidity, and soil moisture in vertical farms for testing on medium-sized crops. Based on the observations it is known that the types of plants observed are water spinach and beach sunflowers. Both of these plants have the following optimal growth criteria:

Table 1. Vertical Garden Plant Criteria

Plant Name	Temperature (°C)	Moisture (%)	Soil moisture (%)
cabbage	20 - 32	80	55 - 60
sun beach	27	60 - 75	60 - 70

In the system schematic, make a circuit display for hardware design, here is the design view:

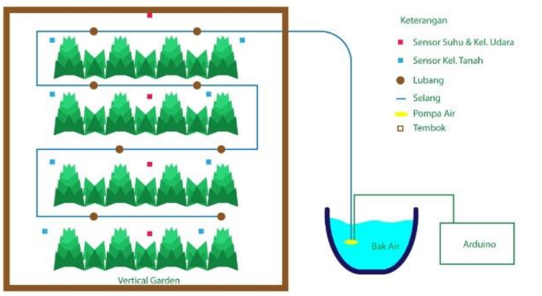

Figure 2 Plant Vertical System Design

The microcontroller circuit design model (Arduino) is described in Figure 3:

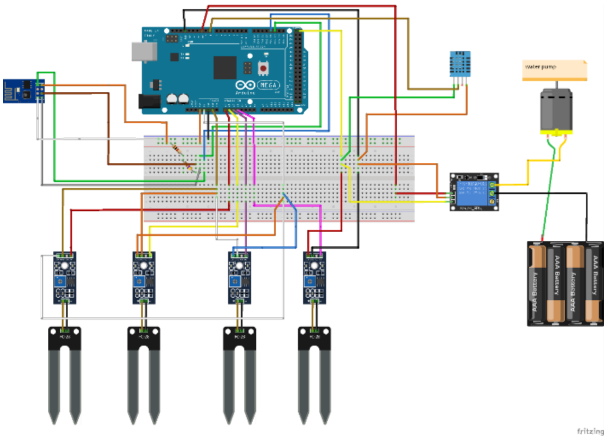

Figure 3 Hardware circuit design

Adaline Algorithm Implementation: The implementation stages in this study will be directed at two processes, namely the pre-processing data stage and the Adaline Neural Network training process. Where inputs and targets are trained with a network that has been built to obtain the weight of the learning which is then used as the basis for calculating the next incoming training data. Data Pre-Processing Stage. In this classification process, the data that has been collected will be normalized so that it can be used in Adaline. Normalization is done if the initial value (N) or the value before normalization is ≤ the middle value, then the normalization formula is:

$$N' = \frac{Nmiddle\ value - N}{Max - Min} \tag{1}$$

However, if the initial value (before being normalized) > the middle value, the normalization formula is as follows:

$$N' = \frac{N - Min}{Max - Min} \tag{2}$$

Where, N'= normalized value, N = initial value, Max = maximum value, Min = minimum value.

Adaline's algorithm is used for the Artificial Neural Network training process. Where inputs and targets are trained with a network that has been built to obtain the weight of the learning which is then used as the basis for calculating the next incoming training data.

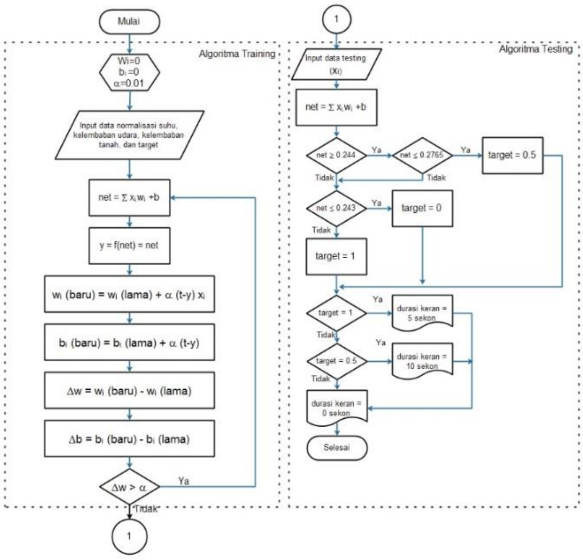

Figure 4 Adaline's Algorithm in the System.

The explanation of the algorithm above is:

1. Initialize initial weight value (wi), initial bias (b1), and tolerance value (α).
2. Enter the input data that has been normalized before. Input data consists of parameters of temperature, air humidity, and soil humidity, as well as normalized target data.
3. Calculate net worth
4. Calculating y or f (net) values
5. Calculating the value of wi (new)
6. Calculating the bi value (new)
7. Calculating the difference between wi (new) and wi (old)
8. Calculating the difference between bi (new) and bi (old)
9. Is the value Δw> α. If yes, repeat step 3
10. If not, enter new data that has been obtained from the sensor readings (xi).
11. Count net
12. If the net is ≥0.244 and ≤0.2765, then target = 0.5
13. If net ≤0.243, then target = 0
14. If not both, then target = 1
15. If target = 1, then flush duration = 5 seconds
16. If target = 0.5, then flush duration = 10 seconds
17. If target = 0, then flush duration = 0 seconds or not active.

System Testing: For system testing, the authors use the MAPE (Mean Percentage Error) method which is a measure of relative accuracy used to determine the percentage deviation of forecasting results with the following equation [28]:

$$MAPE = \frac{100\%}{n} x \sum \left| \frac{Xt - Ft}{Xt} \right| \quad (3)$$

Where, n = total data, Xt = actual data, Ft = data processed by the method.

3. RESULTS

Results and Discussion Adaline Algorithm data collection was carried out by observation by taking data from the DHT11 sensor and YL-69 soil moisture sensor on vertical agriculture, with special media for land plants, namely kale and beach sunflowers. The data that has been obtained from the sensor readings are processed using data normalization techniques. The following is the input data from the observation results:

Table 2. Data Input Sun Beach

No.	Temperature (˚C)	Moisture (%)	Soil moisture (%)
1	29	56	88.5
2	29	56	89.75
3	29	56	89.25
4	29	56	90
5	28	57	88.75
6	30	86	89
7	30	83	89.75
8	29	56	3.25
9	29	59	1.75
10	31	87	1.25
11	30	88	4.75
12	29	60	1.75

Table 3. Data Input Cabbage

No.	Temperature (˚C)	Moisture (%)	Soil moisture (%)
1	29	56	88.5
2	29	56	89.75
3	29	56	89.25
4	29	56	90
5	28	57	88.75
6	30	86	89
7	30	83	89.75
8	29	56	3.25
9	29	59	1.75
10	31	87	1.25
11	30	88	4.75
12	29	60	1.75

Adaline's Training Algorithm. The application of Artificial Neural Networks (ANN) especially the Adaline algorithm in this automatic sprinkler system requires a clear analysis. To analyze system requirements, a knowledge base related to Adaline is needed which will later be used as a reference in designing the system. The knowledge base created in this study can be seen in the table below:

Table 4. Knowledge Base

Indicator	Duration of Tap Opened		
	Short (5 seconds)	Long (10seconds)	Off (seconds)
Temperature	$20℃ - 24℃$	$> 24℃$	$< 20℃$
Moisture	$59\% - 63\%$	$< 59\%$	$> 63\%$
Soil Moisture	$35\% - 64\%$	$< 35\%$	$> 64\%$

Table 5. Training Data Matrix

Indicator	Duration of Tap Opened		
	Short (5 seconds)	Long (10seconds)	Off (seconds)
Temperature	1	1	0.5
Moisture	0	0.5	1
Soil Moisture	0.5	1	0

Table 6. Target Data Matrix

Duration of Tap Opened	Short (5 seconds)	Long (10seconds)	Off (seconds)
Output Target	1	0.5	0

In this training algorithm, based on normalized input data, the training data matrix and the target data matrix will produce weight values (w) for temperature, air humidity and soil humidity, and bias values (b). This value will be entered into the test algorithm. Adaline's Testing Algorithm. The next step is to enter the test data, namely the data obtained by the sensor after 10 readings of temperature, humidity, and soil moisture in vertical farming.

Table 7. Data Testing

Loop	Temperature (˚C)	Moisture (%)	Average Soil Moisture (%)
1	29.00	56.00	49.00
2	29.00	56.00	49.50
3	29.00	56.00	45.50
4	32.00	87.00	48.00
5	32.00	87.00	51.50
6	30.00	83.00	49.25
7	30.00	60.00	50.00
8	29.00	58.00	49.50
9	30.00	57.00	48.75
10	29.00	58.00	52.25

From the results of normalized table 7, the net average value is calculated using the equation. And obtained an average value from the test data of 0.36. Based on the net average values above, and see the activation function table below:

Table 8. Activation Function

Value Net	≤ 0.243	$0.244 - 0.2765$	≥ 0.2766
Output Target	0	0.5	1
Duration of Tap Opened	Off (0s)	Long (10s)	Short (5s)

Since the net value is more than 0.2766 then the target value is 1 which means the flush duration is 5 seconds.

Testing the system using the MAPE method, the results of system testing using the Adaline algorithm are described as follows:

Table 9. Testing Results

No.	**Temperature (°C)**	**Moisture (%)**	**Soil Moisture (%)**	**Flush duration Actual (Seconds)**	**Flush duration Adaline (Seconds)**	**Deviasi Absolut**
1	29	56	88.5	5	5	0
2	29	56	89.75	5	5	0
3	29	56	89.25	5	5	0
4	29	56	90	5	5	0
5	28	57	88.75	5	5	0
6	30	86	89	0	0	0
7	30	83	89.75	0	0	0
8	29	56	3.25	5	5	0
9	29	59	1.75	5	5	0
10	31	87	1.25	10	0	1
11	30	88	4.75	10	0	1
12	29	60	1.75	5	5	0
13	29	56	49	5	5	0
14	29	56	45.5	5	5	0
15	32	87	51.5	0	0	0
16	30	83	49.25	0	0	0
17	30	60	50	5	5	0
18	29	58	49.5	5	5	0
19	30	57	48.75	5	5	0
20	29	57	40.5	5	5	0
21	29	57	73.25	5	5	0
22	29	57	76	5	5	0
23	29	56	75.5	5	5	0
24	29	59	77.75	5	5	0
Jumlah						2
MAPE						8.30 %

The MAPE value uses this equation, then:

$$MAPE = \frac{100\%}{n} x \sum \left| \frac{Xt - Ft}{Xt} \right|$$

$$MAPE = \frac{100\%}{24} x\, 2$$

$$MAPE = 8.3\%$$

Then the calculation accuracy value with the Adaline algorithm can be seen as follows:

$$\text{accuracy} = 100\% - MAPE$$
$$\text{accuracy} = 100\% - 8.3\%$$
$$\text{accuracy} = 91.7\%$$

4. CONCLUSION

From the results of the research conducted, it can be concluded that the manufacture of automatic sprinklers that can do the watering process automatically on vertical farming using the Arduino Mega 2560 microcontroller which is supported by built-in software and combined with several mutually supporting components. . The series of supporting tools for this tool are DHT11 temperature and humidity sensor, YL-69 soil moisture sensor, ESP8266 WiFi module, and relay. And also an integrated circuit with an Android-based application through a MySQL database and a web server that will display information about sensor readings so that the factory owner can monitor anywhere and anytime while connected to the internet network. And it can be proven that Adaline can optimize the decision to determine the duration of the flush by producing an accuracy of 91.7%.

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