

# IoT-Based Smart Monitoring and Controlling System for Shallot Planting Medium Conditions Using a Combination of Context-Aware and Fuzzy Logic Algorithms

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## Abstract

Shallot is a high-risk horticultural product and fall under the category of short-lived plant. Additionally, shallot growth depends on environmental variables such as temperature, soil moisture, pH, and humidity. However, Indonesian farmers face difficulties in maintaining optimal shallot growth, as they primarily rely on weather conditions and do not use specialized equipment to monitor soil conditions. Therefore, a monitoring and control system is needed as a solution to maintain the optimum growth parameters of shallot. This study proposed a system capable of monitoring and controlling the soil conditions for shallots using IoT technology, applying context-aware and fuzzy logic algorithms to control the actuator. The proposed system was developed to control the soil conditions using three specific liquids: neutral water, pH-lowering, and increasing liquid. As parameter control variables, these liquids were utilized to control the soil pH, soil temperature, and soil moisture. A microcontroller controlled the system based on a context-aware algorithm analysis, converting sensor data into context information. Then, fuzzy logic was used to control the liquid pump. The result demonstrates high sensor accuracy, with a coefficient of determination greater than 0.9, indicating that the sensor measurements closely match those of reference instrumentation devices. Moreover, the proposed system successfully handles various conditions by processing information through a context-aware algorithm and using it as control parameters of fuzzy logic.

*Keywords:* Context aware; Fuzzy logic; IoT; Shallot; Smart system

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## 1. Introduction

Shallot (*Allium cepa* var. *Aggregatum* L) is a high economic value agriculture product and considered as high-risk horticultural commodities due to their short life cycle [1]. As a result, shallot growth is heavily dependent on the environment factors. Temperature, soil moisture, soil pH, and humidity play important roles in influencing plant growth. An unstable environment makes shallots more vulnerable to diseases, which can easily attack and cause the plants to wither. [2]. However, farmers in Indonesia still depend on the weather and seasons and they do not use specific equipment to monitor the soil. As a result, production fails to meet demand because its growth can be easily disrupted [3].

Shallot requires several growth factors to be met for optimal growth, particularly regarding soil

conditions. Specific treatments are necessary to maintain this growth, including soil moisture levels of 50-70%, a soil temperature of 25-32 oC, and a soil pH of 5.5-6.5 [2], [3], [4]. These parameters are critical as they can affect the growth and root quality [2]. Traditional farmers face challenges in controlling and monitoring the growth parameters. Therefore, controlling the environment is critical for maintaining optimal growth, particularly in the planting medium. Moreover, system monitoring is necessary to oversee shallot growth.

Internet of Things (IoT) technology can be used as a solution for monitoring and controlling the soil condition. Additionally, IoT is widely used in various applications, particularly in monitoring systems [5]-[9]. IoT can wirelessly connect and communicate multiple devices, exchanging data and converting it

into useful information without human intervention. This technology offers versatility and can be combined with other methods to create effective solutions.

Several studies have proposed various methods that combine IoT technology, such as weather prediction. In these cases, IoT is used to connect multiple sensors, enabling data collection. The data were then processed using machine learning to predict the weather [10]. Another application used machine learning to make prediction based on the soil pH value [11]. Besides prediction applications, IoT technology is widely used for monitoring and controlling agricultural activities, such as irrigation [12]. In this study, the system was used as a reference to develop a monitoring and control system to maintain optimal soil conditions for shallot. However, the previous system lacks an effective control mechanism, as it relies on an on-off controller for the actuator. While the on-off controller is simple and low-cost method, yet it lacks precision [13].

Another approach proposed in previous studies is the use of artificial intelligence (AI) to improve control performance. Fuzzy logic, an AI algorithm, uses fuzzy sets as object classes to define boundaries for membership transition. Therefore, fuzzy logic uses the if-then algorithm regarding the membership transition. Moreover, fuzzy logic needs rules to distinguish the membership, which is called fuzzy rules [14]. This algorithm is considerably efficient yet challenging. Hence, context-based information can be utilized to improve the fuzzy logic performance in assigning the optimal rules. Context-aware algorithms can interpret data into meaningful information and adjust it to distinguish context, such as definition and decision. This context data can then be used to guide control activities. Overall, the context-aware algorithm comprises four general processes: acquiring information, storing context information, and context interpretation [15], [16]. Thus, the context-aware algorithm can be combined with other methods, such as fuzzy logic.

This study proposes a system to control and monitor the soil conditions of the shallot. The system utilizes IoT technology to monitor soil conditions and display the data in a mobile application. Additionally, this system uses two methods to process the data and convert it into control parameters, which are then used by the fuzzy logic controller to control the actuator. Fuzzy logic is utilized in this study because the algorithm can map inputs and interpret them to generate outputs based on the input parameters. The

key parameters that need to be monitored and controlled are moisture, temperature, and pH of soil. Thus, this study aims to design a system that monitors and controls the soil conditions of shallots by combining context-aware and fuzzy logic algorithms, utilizing IoT technology.

Several studies have proposed methods for controlling and monitoring soil conditions. Table 1 summarizes previous research on methods used to control and monitor soil conditions through the implementation of IoT technology. The summary shows that soil moisture was the common measured parameter while communication over Wi-Fi was frequently used for transferring the data to the monitoring system. However, some previous systems lacked control features, and most relied solely on on-off controllers. This study offers both monitoring and control features. The proposed system includes additional data processing to gather information on soil conditions, which is then used as control parameters. These parameters are applied to control liquid pumps, ensuring optimal soil conditions are maintained.

## **2. Research Method**

### **2.1 Proposed System**

Fig. 1 shows a block diagram of the proposed design, illustrating the system's configuration. The system consists of five main : sensor as the input, the microcontroller as the controller, the IoT platform as a data communication bridge between the microcontroller and mobile application, and the actuator. The proposed system used three sensors: a temperature sensor, a pH sensor, and a soil moisture sensor. These sensors collect data on soil conditions, which is then transmitted to the microcontroller as control parameters. The microcontroller uses this data to control the actuator, which operates three liquid pumps in the system.

Microcontroller ESP8266 was used in the system for controlling the actuator and managing data communication between the hardware and software via the IoT platform. The IoT platform receives the data from the microcontroller via Wi-Fi using the Hypertext Transfer Protocol (HTTP). Both communication methods are also utilized for communication between the IoT platform and the mobile application, which is designed for the android platform The application provides several functions, displaying useful information to the user, such as soil moisture, soil temperature, and soil pH.

Table 1. Comparison of the existing methods

References	Year	Measured Parameters	Communication Technology	Monitoring Features	Controlling Features	Controlling Method
[8]	2021	Soil moisture	Wi-Fi	Yes	No	No
[7]	2022	Temperature and Humidity	LoRa	Yes	No	No
[17]	2022	Ambient temperature, air humidity, soil moisture	Wi-Fi	Yes	Yes	On-off controllers
[9]	2022	Rain sensor, oil moisture, and water level	Wi-Fi	Yes	Yes	On-of controllers
[18]	2022	Soil moisture	Wi-Fi	Yes	No	No
[12]	2022	Soil moisture, wind speed, and air temperature	Wi-Fi	Yes	Yes	On-off controllers
[19]	2023	Soil moisture and soil pH	Wi-Fi	Yes	Yes	On-off controllers
[20]	2023	Soil temperature, soil moisture, and soil pH	LoRa and cellular	Yes	No	No
[3]	2024	Soil pH, ambient temperature, and air humidity	Wi-Fi	Yes	Yes	On-off controllers
[21]	2024	Soil moisture and soil pH	LoRa	Yes	No	No
This study	2024	Soil moisture, soil temperature, soil pH	Wi-Fi	Yes	Yes	Context Aware and Fuzzy Logic

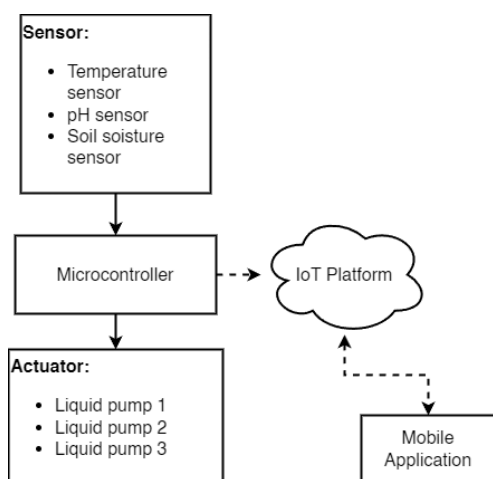


Fig. 1. The architecture of the proposed system

The proposed system combines context-aware and fuzzy logic algorithms and is designed to maintain optimal shallot growth. It regulated soil moisture between 50% to 70%, soil temperature between 25oC and 32oC, and soil pH between 5.5-6.5. These parameters are used by the context-aware algorithm as information and fuzzy logic as control parameters. The context-aware algorithm processed the data into context information, which was then used to trigger system actions. The fuzzy logic algorithm interpreted this context information and issues action commands by adjusting the liquid pump's speed accordingly.

Fig. 2 depicts the flowchart of the algorithm used in the proposed system to control the actuator. The

system began by collecting data from sensors, such as soil moisture, soil temperature, and soil pH sensors. The collected data is then processed by the context-aware algorithm to generate context information, which is utilized by the fuzzy logic algorithm to issue commands to the actuator. The actuator runs until the desired conditions are met.

The context-aware algorithm processes sensor data and converts the readings into context rules. Each sensor provided information that was processed by both the context-aware and fuzzy logic algorithms. For instance, a context rule might state that if the humidity is below 50%, water will be added until it exceeds 50%, and the temperature must remain below 32°C. For pH, two variables were monitored: acidic and alkaline. Therefore, two different substances must lower or raise the pH. Overall, the context rule is shown in Table 2.

Fuzzy logic controls the actuator based on the context information, using three stages: fuzzification, inference, and defuzzification, to regulate the speed of the liquid pump. Fuzzification creates a membership of every control parameter, soil moisture, soil temperature, and soil pH based on the optimum growth conditions for shallots. This process clarified the degree of membership for each control parameter.

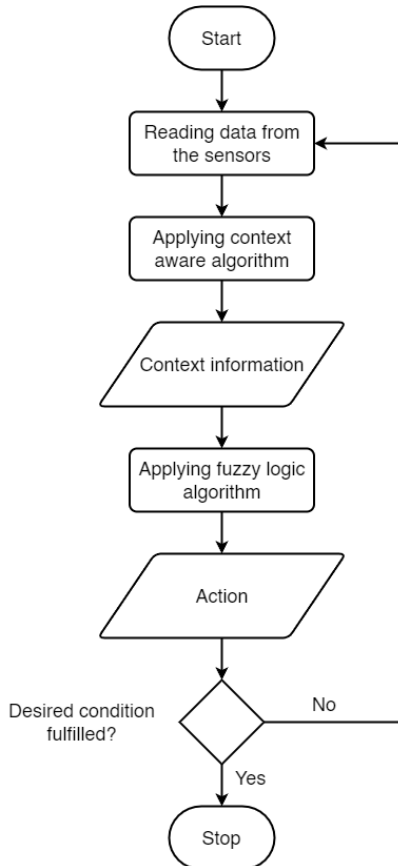


Fig. 2. Flowchart of control algorithm system

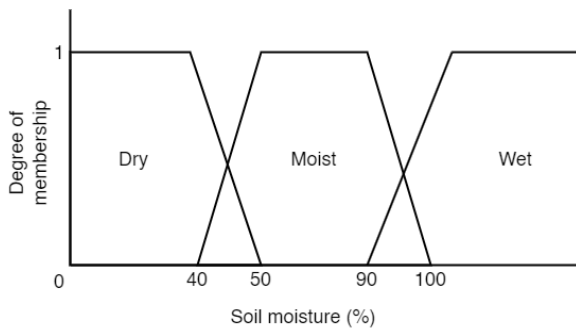


Fig. 3. Fuzzy membership function of soil moisture

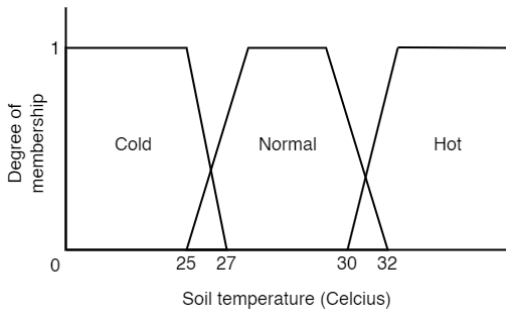


Fig. 4. Fuzzy membership function of soil temperature

Fig. 3 depicts the membership function for soil moisture, which consists of three categories: dry, moist, and wet. The dry member category is below 40%, moist is 40% to 100%, and wet is above 100%. The membership degree is calculated following Eq. 1, Eq. 2, and Eq. 3.

$$\mu [dry] = \begin{cases} 1; & x < 40 \\ \frac{50-x}{10}; & 40 < x < 50 \end{cases} \quad (1)$$

$$\mu [moist] = \begin{cases} \frac{x-40}{10}; & 40 < x < 50 \\ 1; & 50 < x < 90 \\ \frac{100-x}{10}; & 90 < x < 100 \end{cases} \quad (2)$$

$$\mu [wet] = \begin{cases} \frac{x-90}{10}; & 90 < x < 100 \\ 1; & x > 100 \end{cases} \quad (3)$$

Fig. 4 illustrates the membership function for soil temperature. In this study, soil temperature membership is divided into three categories: below 25oC for cold, 25 oC to 32 oC for normal, and above 32 oC for hot. The membership degree is calculated using Eq. 4, Eq. 5, and Eq. 6.

$$\mu [cold] = \begin{cases} 1; & x < 25 \\ \frac{27-x}{2}; & 25 < x < 27 \end{cases} \quad (4)$$

$$\mu [normal] = \begin{cases} \frac{x-25}{2}; & 25 < x < 27 \\ 1; & 27 < x < 30 \\ \frac{32-x}{2}; & 30 < x < 32 \end{cases} \quad (5)$$

$$\mu [hot] = \begin{cases} \frac{x-30}{2}; & 30 < x < 32 \\ 1; & x > 32 \end{cases} \quad (6)$$

$$\mu [acid] = \begin{cases} 1; & x < 5 \\ \frac{5.5-x}{0.5}; & 5 < x < 5.5 \end{cases} \quad (7)$$

$$\mu [neutral] = \begin{cases} \frac{x-5}{0.5}; & 5 < x < 5.5 \\ 1; & 5.5 < x < 6.5 \\ \frac{7-x}{0.5}; & 6.5 < x < 7 \end{cases} \quad (8)$$

$$\mu [alkaline] = \begin{cases} \frac{x-6.5}{0.5}; & 6.5 < x < 7 \\ 1; & x > 7 \end{cases} \quad (9)$$

Similar to other membership functions, soil pH is divided into three categories: acid (less than 5), neutral (between 5 and 7), and alkaline (larger than 7), each with different measurement ranges. The acid category is presented in Fig. 5. The membership degree in this category is calculated following Eq. 7, Eq. 8, and Eq. 9.

Table 2. Context rule of the system

Context	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Neutral Water Pump	pH-Increasing Pump	pH-Lowering Pump
1	<50	>32	<5.5	OFF	ON	OFF
2	<50	25-32	<5.5	OFF	ON	OFF
3	<50	<25	<5.5	OFF	ON	OFF
4	50-70	>32	<5.5	OFF	ON	OFF
5	50-70	25-32	<5.5	OFF	ON	OFF
6	50-70	<25	<5.5	OFF	ON	OFF
7	>70	>32	<5.5	OFF	ON	OFF
8	>70	25-32	<5.5	OFF	ON	OFF
9	>70	<25	<5.5	OFF	ON	OFF
10	<50	>32	5.5-6.5	ON	OFF	OFF
11	<50	25-32	5.5-6.5	ON	OFF	OFF
12	<50	<25	5.5-6.5	ON	OFF	OFF
13	50-70	>32	5.5-6.5	ON	OFF	OFF
14	50-70	25-32	5.5-6.5	OFF	OFF	OFF
15	50-70	<25	5.5-6.5	OFF	OFF	OFF
16	>70	>32	5.5-6.5	ON	OFF	OFF
17	>70	25-32	5.5-6.5	OFF	OFF	OFF
18	>70	<25	5.5-6.5	OFF	OFF	OFF
19	<50	>32	>6.5	OFF	OFF	ON
20	<50	25-32	>6.5	OFF	OFF	ON
21	<50	<25	>6.5	OFF	OFF	ON
22	50-70	>32	>6.5	OFF	OFF	ON
23	50-70	25-32	>6.5	OFF	OFF	ON
24	50-70	<25	>6.5	OFF	OFF	ON
25	>70	>32	>6.5	ON	OFF	OFF
26	>70	25-32	>6.5	OFF	OFF	ON
27	>70	<25	>6.5	OFF	OFF	ON

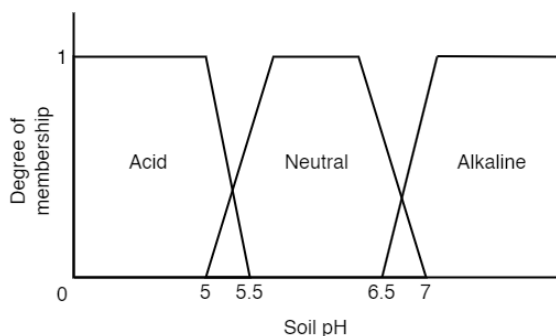


Fig. 5. Fuzzy membership function of soil pH

The next stage of the fuzzy logic algorithm was the inference process, where the rules were applied to combine each control parameter and generate an output for each rule. The microcontroller will utilize the output of the fuzzy rules to command the actuator by providing pulse width modulation (PWM), which adjusts the flow speed of the liquid pump. The fuzzy logic rules are shown in Table 3.

In the last stage, defuzzification was carried out to complete the inference process, yielding a crisp value using the Centroid (CoA) method. The CoA method

converts the membership function ( $\mu$ ) to obtain the crisp value for each classification as shown in Eq. 10.

$$CoA = \frac{\int x \mu(x) dx}{\int \mu(x) dx} \quad (10)$$

### 2.2 Hardware Design

The hardware configuration of the proposed system includes both the electronic configuration and the shallot planted medium. As depicted in Fig. 6, the planting medium is constructed using a PVC pipe, 50 cm in length and 4 inches in diameter. The pipe is cut into two parts; one serves as the shallot planting medium, and the other houses the actuator. The overall design of the shallot planted medium are 43 cm in length, 20 cm in width, and 47 cm in height. The design also accommodates three containers, each holding liquid to help control soil conditions.

Fig. 7 depicts the electronic configuration used in this study. The setup includes various components, such as a soil moisture sensor, a pH sensor, a soil temperature sensor, three water pumps, a motor driver, an extended ADC module, a step-down module, and the ESP8266. The ADC module is necessary for the pH and soil moisture sensor output since they output

analog signals, and the ESP8266 only has has only one analog input pin. The temperature sensor and motor driver are connected to the digital pins of the ESP8266. The motor driver requires a 12V power supply, which the microcontroller cannot provide, so an external 12V power source was needed. The power supply was connected through a stepped-down module (XL4105), which regulates the voltage and current for the components. The XL4105 module connects to a 2.1 mm female jack port, which linked to the external power supply.

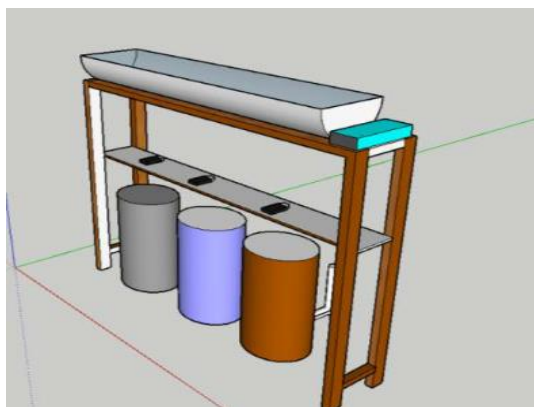


Fig. 6. The design of the shallot planted medium and the container for a neutral water, a pH-lowering liquid, and a pH-increasing liquid

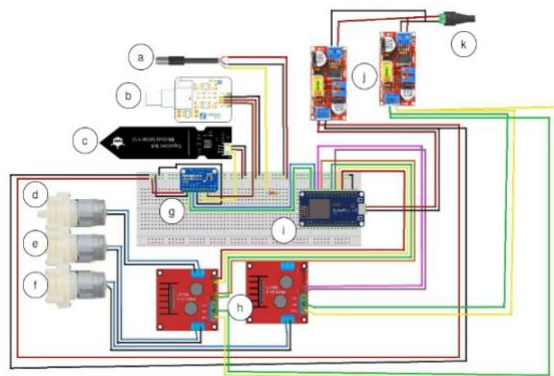


Fig. 7. The electronic hardware configuration; (a) soil temperature sensor, (b) soil pH sensor, (c) soil moisture sensor, (d) neutral water pump, (e) pH-lowering pump, (f) pH-increasing pump, (g) ADC module, (h) motor driver module, (i) ESP8266, (j) step-down module, and (k) 2.1 mm jack port.

### 2.3 Application Design

Fig. 8 shows the design of the proposed monitoring system's Android application. The application included three main features to accommodate the user: communication settings, data display, and status display of actuator and soil condition. The communication setting feature includes a data recording button and options for real-

time or non-real-time data display. The data display shows sensor measurements to the user during operation, including soil moisture, soil temperature, and soil pH. Lastly, the status display shows the condition of the three actuators and the soil, indicating whether the actuators are running and if the soil condition is in optimal condition.

Table 3. The Fuzzy Logic Rule to Control the Actuator

Soil Moisture	Soil Temperature	Soil pH	Output
Dry	Hot	Acid	Fast
Dry	Normal	Acid	Normal
Dry	Cold	Acid	Slow
Moist	Hot	Acid	Normal
Moist	Normal	Acid	Slow
Moist	Cold	Acid	Slow
Wet	Hot	Acid	Slow
Wet	Normal	Acid	Slow
Wet	Cold	Acid	Slow
Dry	Hot	Neutral	Fast
Dry	Normal	Neutral	Normal
Dry	Cold	Neutral	Slow
Moist	Hot	Neutral	Normal
Moist	Normal	Neutral	Off
Moist	Cold	Neutral	Off
Wet	Hot	Neutral	Slow
Wet	Normal	Neutral	Off
Wet	Cold	Neutral	Off
Dry	Hot	Alkaline	Fast
Dry	Normal	Alkaline	Normal
Dry	Cold	Alkaline	Slow
Moist	Hot	Alkaline	Normal
Moist	Normal	Alkaline	Slow
Moist	Cold	Alkaline	Slow
Wet	Hot	Alkaline	Slow
Wet	Normal	Alkaline	Slow
Wet	Cold	Alkaline	Slow

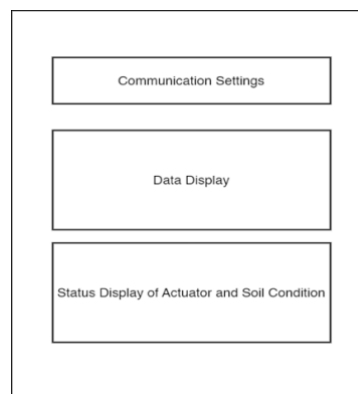


Fig. 8. The interface appearance of the application design

### 3. Result and Discussion

Fig. 9 shows the implementation of the soil monitoring and control device. The device consists of three liquid containers, a soil container for shallot planting medium, three pumps, and a controller. The liquid containers held different solutions: a pH-increasing liquid, neutral water, and a pH-decreasing liquid. Each container was connected to a pump via water channels or hoses. The pump has two ports with distinct functions: an input and an output. The input port connects the pump to the liquid container, while the output port directs the liquid through water channels to the soil container and shallot planting medium. The controller, responsible for monitoring soil conditions, was installed on the device. It was built using the components described in the hardware design section and implemented as shown in Fig 10.

In this study, each sensor was calibrated to ensure precise measurements. The first calibration performed was for soil moisture. The calibration of the soil moisture sensor was conducted using values from dry soil conditions (0%) and wet soil conditions (100%) through a two-point calibration method. Dry soil was obtained by drying it under direct sunlight and then further heating it using roasting methods, while wet soil was created by adding water until it became saturated. The ADC values for dry and wet soil conditions were recorded, and these values will be used in the Arduino code mapping, as outlined in Eq. 11 [22].



Fig. 9. The proposed system implementation: (a) the container of neutral water, pH-lowering water, and pH-increasing water, (b) water pump, (c) controller, and (d) shallot planted medium

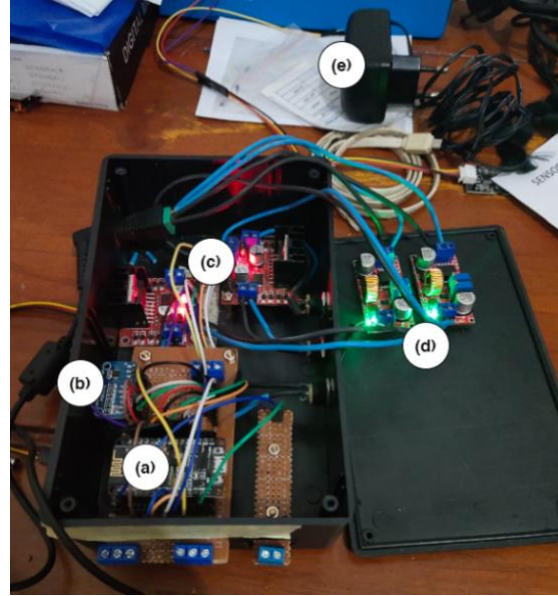


Fig. 10. Hardware implementation: (a) ESP8266, (b) ADC module, (c) motor driver, (d) step-down module, and (e) DC power adaptor

$$M_o = \frac{(x - in\_min) * (out\_max - out\_min)}{(in\_max - in\_min) + out\_min} \quad (11)$$

Where,  $M_o$  and  $x$  represent the moisture level from the mapping calculation and the real-time ADC output value from the soil moisture sensor after conversion by the ADC module, respectively.  $in\_max$  and  $in\_min$  are derived from measurements taken when the soil is wet and dry, respectively. The obtained  $in\_max$  value after measurement was specified in 9328 and  $in\_min$  was 18128. Furthermore,  $out\_min$  and  $out\_max$  represent the minimum and maximum boundaries for the soil moisture percentage that are 0 and 100, respectively. Thus, the code mapping converts the sensor input into the soil moisture percentage range. The results were then compared to manual calculations using Eq. 12 [22].

$$M_s = \frac{m_w - m_d}{m_d} \times 100\% \quad (12)$$

Here,  $M_s$ ,  $m_w$ , and  $m_d$  are soil moisture level in percentage, wet soil mass in grams, and dry soil mass in grams, respectively. Fig. 11 illustrates the relationship between the soil moisture calculation obtained from the sensor and the result from manual calculations. The result shows that the data from the soil moisture sensor correlates well with the result from the manual calculation, as per Eq. 12. The R-squared value of 0.9461 indicates a strong correlation, suggesting that the data from the sensor and the manual calculations move similarly according to this index.

The soil pH sensor was calibrated by comparing the sensor readings with standardized pH solutions. The standard pH values used were 4.01, 6.86, 7.00,

9.18, and 10.01. The pH sensor was dipped in each of these solutions, and the readings were recorded to identify any discrepancies. The sensor was cleaned before each test to ensure that the readings remained unaffected. Before calibrating the pH sensor, the ADC output must first be converted to voltage. The following Eq. 13 is the conversion formula from ADC to pH sensor voltage, where  $V$  represents the voltage value obtained from the ADC-to-voltage conversion,  $y$  is the ADC output value from the sensor, 5 volts is the power supply connected to the sensor, and 65536 is the resolution of the 16-bit extended ADC module.

$$V = \frac{5V}{65536} \times y \quad (13)$$

Fig. 12 depicts that the pH sensor readings closely align with the pH buffer value, demonstrating a strong correlation with a high coefficient of determination of 0.9678. Similarly, the calibration of the soil temperature sensor also exhibits a strong correlation, achieving a coefficient of determination of 0.9909, as illustrated in Fig. 13.

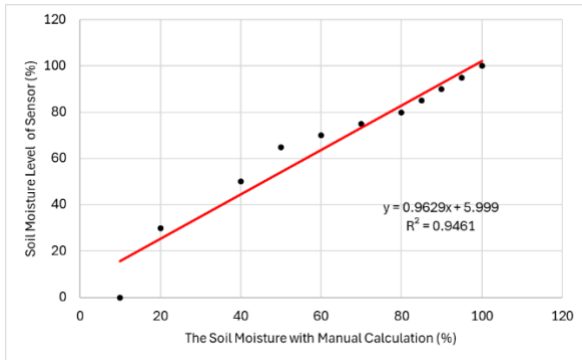


Fig. 11. The correlation graph of the soil moisture with manual calculation data and soil moisture sensor readings

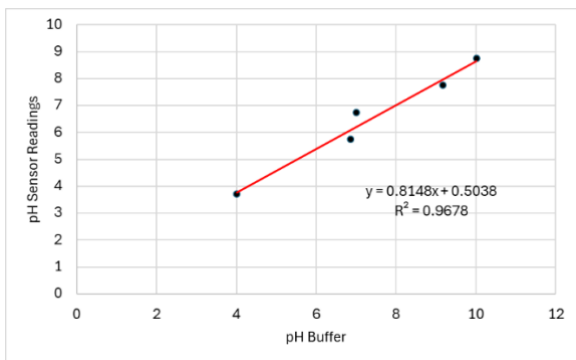


Fig. 12. The correlation graph of pH buffer value and pH sensor readings data

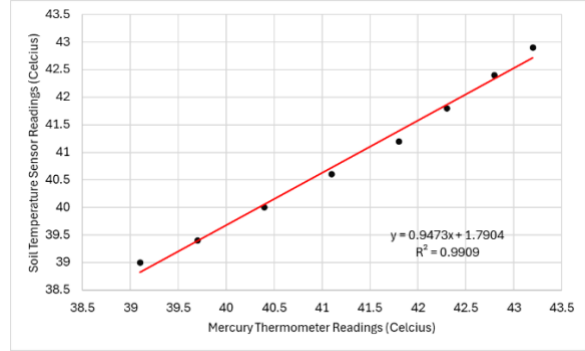


Fig. 13. The correlation graph of mercury thermometer and soil temperature sensor readings

The calibration results indicate that the sensors demonstrate excellent performance, with coefficients of determination exceeding 0.9. This strong performance is expected to positively impact on the overall effectiveness of the proposed system, particularly in controlling the liquid pump. This study involves three liquid pumps, each serving a distinctive function. All-liquid pumps operate based on the control parameters of soil moisture, soil temperature, and soil pH. Hence, achieving high measurement performance ensures accurate data for the microcontroller to analyze, which in return enhances the performance of the fuzzy logic and context-aware algorithm.

Table 4 presents the results sample from the comprehensive testing of the response system.. The system demonstrated its longest operational time under the testing scenario with soil conditions of pH > 6.5, moisture > 50%, and temperature > 32°C by achieving soil optimization for 287 seconds (4 minutes and 47 seconds). According to Table 1, the context-aware algorithm provides context information numbers 22 and 25, indicating two possible actions. Based on the fuzzy rules, the pH-lowering and neutral water pumps will operate at slow and normal speeds, respectively. As a result, these conditions allow for the longest duration to optimize the soil. In contrast, the system achieved its fastest soil optimization in the



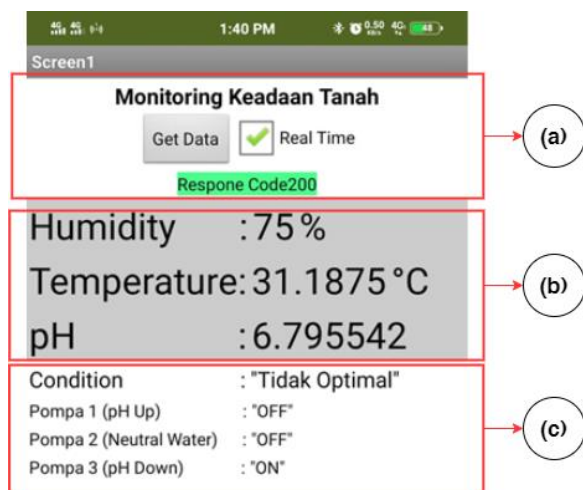


Fig. 14. The interface of the monitoring system: (a) communication settings, (b) data display, and (c) status display of actuator and soil condition

scenario with pH > 5.5, soil moisture > 70%, and optimal temperature, where the system completed optimization in 51 seconds. This condition may result from the context-aware algorithm only instructing the pH-lowering pump to operate, based on the context information in Table 1. Moreover, the system can achieve the fastest optimization by commanding the pump to work at a slow speed, which shortens the pH-reduction process.

Fig. 14 depicts the successfully integrated interface of the monitoring system. The application allows the user to monitor real-time data and actuator conditions by retrieving data from Antares. When the user presses the 'get data' button, the data will be displayed in the application. Additionally, users can

check the 'real-time' checkbox to command the application to continuously retrieve and display real-time data.

Overall, the proposed system demonstrated the expected performance. The sensors can achieve high accuracy, and the monitoring system effectively displayed the required information. This high accuracy is crucial for the fuzzy algorithm to perform optimally. However, the controller's performance requires attention, particularly due to the pH-based control approach. While the liquids used have different contents, they tended to reduce temperature and increase soil moisture. As shown in Table 3, in several cases, soil moisture became too high after optimization. Therefore, the system could be improved by adding more actuators or employing alternative methods to better regulate soil moisture.

#### 4. Conclusions

The context-aware and fuzzy logic algorithm were successfully implemented for monitoring and controlling the shallot planting medium using IoT technology. The proposed system demonstrated high sensor accuracy, with a coefficient of determination exceeding 0.9, indicating that the sensor measurements closely match those of reference instrumentation devices. This high accuracy enables the fuzzy logic algorithm to perform effectively. Additionally, the system successfully managed various conditions through the information processing capabilities of the context-aware algorithm, which served as control parameters for the fuzzy logic. Moving forward, improvements are necessary to enhance the system's ability to control soil moisture more efficiently.

Table 4. Performance result of the proposed system

Before			After			Duration (s)
Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	
30	33.18	3.93	82	29.75	5.94	203
55	33.43	3.95	83	31.81	5.76	101
5	25.25	3.90	53	25.18	5.55	37
68	27.00	3.73	81	27.00	5.73	88
8	33.18	5.61	83	30.37	5.77	102
18	26.50	6.46	63	26.56	5.89	31
62	33.37	5.93	63	30.62	6.46	78
38	33.43	8.11	75	31.25	5.77	210
70	33.31	6.94	82	29.93	5.95	287
8	27.43	7.28	89	27.00	6.34	70
73	30.87	6.63	84	30.81	6.35	51

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