EMITOR: Jurnal Teknik Elektro

Control System for Watering and Lighting of Chrysanthemum Plant in IoT-Based Greenhouse

Siti Aminah*, Fitria Suryatini, Meikeu Melani
Major Automation Engineering – Politeknik Manufaktur Bandung
Bandung, Indonesia
*aminah@polman-bandung.ac.id

Abstract – *An automatic control system based on the Internet of Things (IoT) is essential for intelligent monitoring and regulation of soil moisture and lighting in greenhouse environments, particularly for chrysanthemum cultivation. This study proposes an IoT-based control system integrating fuzzy logic to manage irrigation and lighting according to plant growth phases. An experimental method was employed using an ESP32 microcontroller connected to a soil moisture sensor and a light sensor. Real-time data were transmitted to the Firebase platform and visualized through an Android application developed with Kodular. Fuzzy logic was used to control irrigation based on soil moisture levels, while lighting was controlled via a timer aligned with plant development stages. Experimental results showed that the soil moisture sensor achieved an average accuracy of 82.33%, and the light sensor, after linear regression calibration, reached an accuracy of 98.15%. The fuzzy logic controller demonstrated an average error of 4.35% compared to MATLAB simulations. The irrigation system responded with a 1-minute 12-second delay, 4-minute 31-second rise time, and a 6-minute settling time without overshoot. Communication functionality remained stable at distances over 160 km, and LED lighting significantly enhanced vegetative growth. The mobile application operated effectively across all core features. This system is well-suited for small-scale greenhouse applications, though adaptations are needed for larger or multi-zone deployments.*

Keywords – *Chrysanthemum; Greenhouse; Lighting; Fuzzy logic; Mobile Application.*

I. Introduction

INDONESIA has emerged as a rapidly growing horticultural nation, contributing significantly agricultural development through various commodities including vegetables, fruits, medicinal plants, and floriculture [1]. According to data from BPS (Badan Pusat Statistik), the country ranks among the world's leading producers of ornamental plants [2]. Among these, the cut chrysanthemum (*Chrysanthemum morifolium*) is one of the most popular ornamental plants due to its vibrant colors, diverse petal shapes, and perennial blooming nature [3, 4]. Chrysanthemums are widely used for decoration in hotels, traditional ceremonies, flower arrangements, and are utilized in several industries such as cosmetics, fragrances, and herbal medicine [5, 6].

To cultivate high-quality chrysanthemums, it is essential to maintain environmental conditions such as soil moisture and lighting that align with the plant's growth stages. Greenhouse cultivation offers a controlled environment where key parameters can be optimized. During the vegetative phase (10–25 days), chrysanthemums require soil moisture levels of 70–80%, while in the generative phase (30–35 days), the optimal range drops to 50–60% [7, 8]. Deviations from these levels can hinder root development or lead to wilting and bud drop [9–11]. In terms of lighting, chrysanthemums are classified as short-day plants, requiring 16–18 hours of light during the vegetative phase and 12 hours during the generative phase [12, 13]. Given that tropical regions like Indonesia receive approximately 12 hours of natural light, supplemental lighting becomes necessary, particularly during vegetative growth [14].

The importance of vegetative and generative growth in the chrysanthemum life cycle is substantial, as each phase requires distinct environmental conditions to support optimal development [15]. Vegetative growth involves the increase in plant size and foliage, while generative growth begins with the formation of flower primordia. By controlling the parameters according to each growth phase, farmers can improve crop yields and flower quality.

The manuscript was received on July 7, 2025, revised on July 2, 2025, and published online on July 25, 2025. Emitor is a Journal of Electrical Engineering at Universitas Muhammadiyah Surakarta with ISSN (Print) 1411 – 8890 and ISSN (Online) 2541 – 4518, holding Sinta 3 accreditation. It is accessible at https://journals2.ums.ac.id/index.php/emitor/index.

The application of Internet of Things (IoT) technology in agriculture offers innovative solutions for automating and managing environmental control systems. Real-time data acquisition and monitoring are enabled through sensors connected to a microcontroller platform. These data are transmitted to a cloud-based Firebase platform and visualized via a mobile application developed using Kodular [16–18]. For irrigation control, fuzzy logic is implemented to handle uncertainty in sensor data, allowing precise and adaptive responses based on soil moisture levels [19, 20]. Lighting is managed through a scheduled on/off system that is programmed according to plant growth stages, independent of real-time light intensity readings [21].

Despite the potential of IoT and fuzzy logic in smart farming applications, most previous studies have addressed irrigation or lighting independently, lacking a unified and adaptive control framework. Furthermore, existing research often targets general horticultural scenarios and does not consider the specific environmental requirements of *Chrysanthemum morifolium* across its distinct vegetative and generative phases.

To address this gap, this study proposes the design and development of an IoT-based automatic control system that integrates fuzzy logic for irrigation and time-based lighting control. The system is specifically tailored for chrysanthemum cultivation in greenhouse settings. It is expected that the implementation of this integrated system will improve the efficiency and precision of chrysanthemum farming, while promoting the adoption of smart agricultural technologies in Indonesia.

II. Research Methods

This research applies an experimental method that includes the stages of problem identification, needs analysis, system design, implementation, testing, and evaluation. This method was chosen because it allows for direct testing of the system's effectiveness through structured observation and real measurements. The main issue identified is that conventional methods have not been able to adjust chrysanthemum plant care according to their growth phases. To address this issue, an IoT-based automatic system equipped with sensors and actuators was developed to efficiently regulate watering and lighting. After the system was designed and implemented, performance testing and evaluation were conducted. If discrepancies are found, corrections are made until the system operates as expected, as shown in Figure 1.

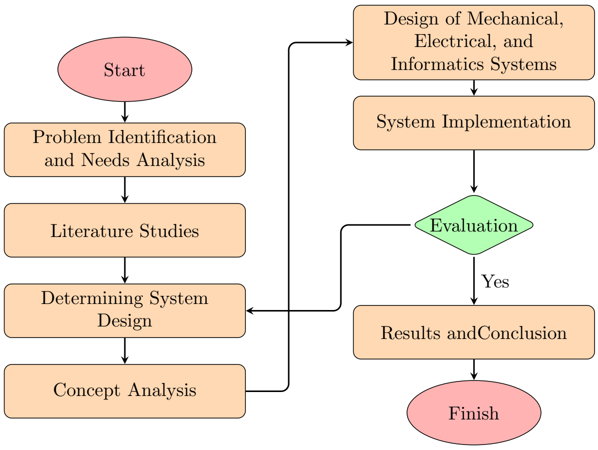


Figure 1: Research Methodology Flowchart

i. Overview of the System

In the overview of the system shown in Figure 2, it is designed to monitor and control the humidity and lighting of the plants. Sensors detect environmental conditions, where watering is automatically controlled using fuzzy logic methods, while lighting is regulated based on a timer. The ESP32 microcontroller sends real-time data to Firebase, and users can monitor and control the system through a Kodular-based Android application.

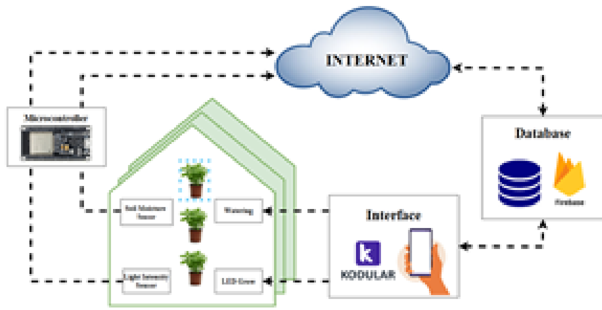
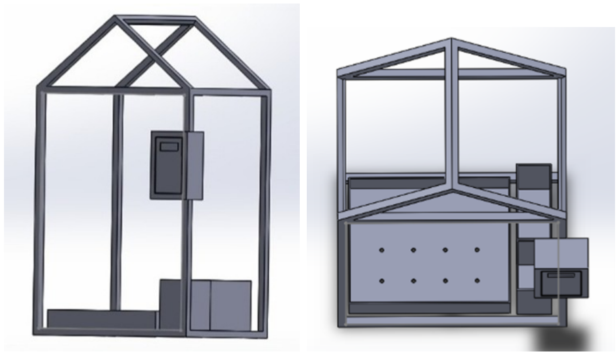


Figure 2: Overview of the System

ii. Mechanical Design

The details of the mechanical system design include dimensions of 85 cm in length, 60 cm in width, and 140 cm in height. Because chrysanthemum plants will grow tall, the height of the greenhouse must be taller than the plants. During the watering of the chrysanthemum plants, the pipe will be placed at the top center of the greenhouse so that not only the roots of the plants are watered, but also the leaves and stems as shown in Figure 3.



(a) (b)

Figure 3: Mechanical design

iii. Electrical Design

In this research, the mechanical design includes the creation of a framework to unite components, planting media, and the greenhouse. The process begins with 3D design, followed by manufacturing either manually or with machines according to the design, as shown in Figure 4.

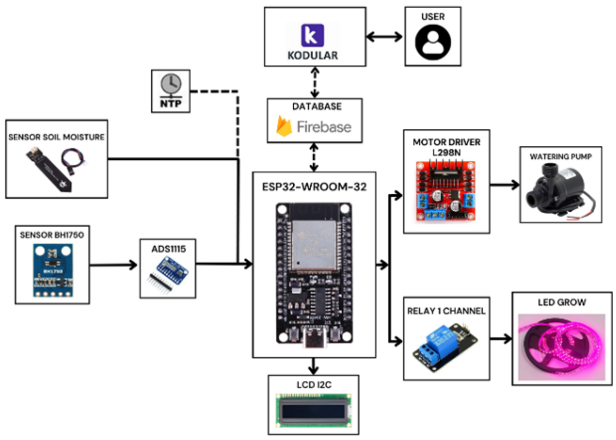


Figure 4: Electrical Design

In Figure 4, an overview of the control system for watering and lighting chrysanthemum plants in the greenhouse is shown. This system uses the ESP32 microcontroller for data acquisition and collection from the light sensor (BH1750) and soil moisture sensor. The ESP32 also processes the data and communicates via WiFi. The BH1750 sensor measures light intensity (lux) and the moisture sensor measures soil water content (%). The output includes a DC pump for watering, and grow LEDs for nighttime lighting, with a motor driver to adjust the pump speed. The I2C LCD is used to display sensor data. The process begins with the microcontroller processing sensor data and sending it to the serial monitor and Firebase via IoT. The data in Firebase can be accessed through the Kodular application. The microcontroller continuously updates the data and controls the water pump if the humidity is low, activating the grow LED from 6:00 PM to 6:00 AM when the light intensity decreases. Data from the sensor is also displayed on the I2C LCD and panel.

iv. Control System Design

The control system used in this research is the fuzzy logic control system and the timer control system, as shown in Figure 5.

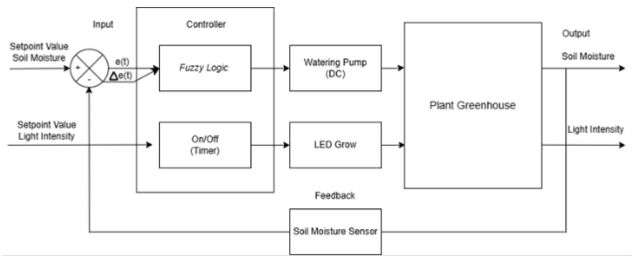


Figure 5: Control System Design

Setting the soil moisture setpoint uses fuzzy logic control based on feedback from sensors to maintain optimal conditions. Meanwhile, lighting is controlled with a timer without direct feedback; sensors are only used for monitoring and manual adjustments if necessary.

v. Design of the Sugeno Fuzzy Logic System

The Sugeno fuzzy logic method, which takes into account the uncertainty of environmental conditions, is used to optimally control soil moisture. In this system, there are two input variables: error (the difference between the setpoint and the moisture sensor value) and Δerror (the change in error over time). The error value is divided into four fuzzy sets: Z3 (dry soil), Z2 (medium soil), Z1 (wet soil), and Z (additional to prevent overshoot). Meanwhile, Δerror consists of three fuzzy sets: Nd (negative), Zd (neutral), and Pd (positive). The combination of these two inputs is used to make more reliable and efficient watering decisions, in order to maintain optimal plant conditions, as shown in Figures 6 and 7.

The output variable, which is the pump speed, is divided into four levels: the *STOP* variable with a PWM value of 0, *SLOW* with PWM 150, *MEDIUM* with PWM 200, and *FAST* with PWM 230, as illustrated in Figure 8.

After defining the sets for each input and output, the next step is to formulate rules based on the combination of error values and changes in error (Δerror), which are shown in Table 1.

The resulting fuzzy rules are as follows:

1. Rule 1: If error Z and delta error Nd then Pump Speed = Stop.

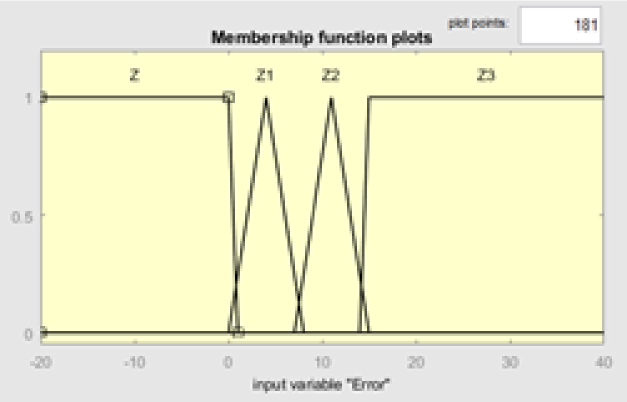


Figure 6: Set of Input Error Values

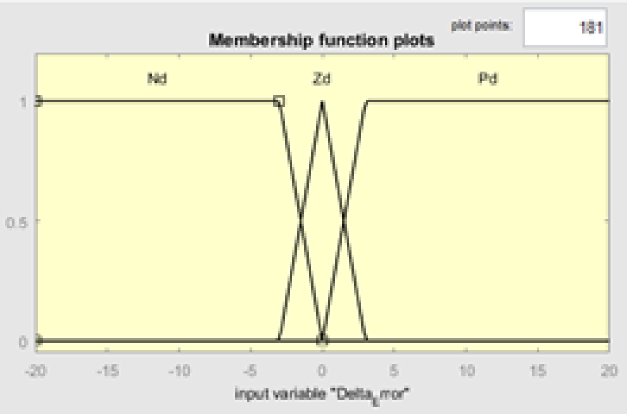


Figure 7: Set of Input Delta Error Values

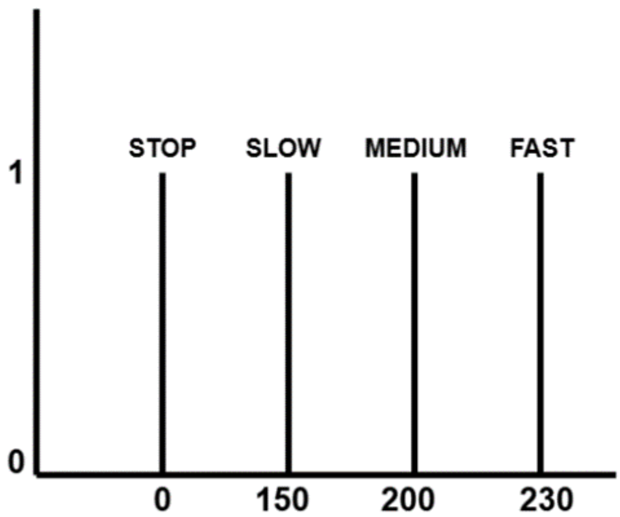


Figure 8: Set of Output Pump Speed

Table 1: Rule Base

ΔError	Z3	Z2	Z1	Z
Pd	Fast	Fast	Medium	Stop
Zd	Fast	Medium	Slow	Stop
Nd	Medium	Medium	Slow	Stop

2. Rule 2: If error Z and delta error Zd then Pump Speed = Stop.
3. Rule 3: If error Z and delta error Pd then Pump Speed = Stop.
4. Rule 4: If error Z1 and delta error Nd then Pump Speed = Slow.
5. Rule 5: If error Z1 and delta error Zd then Pump Speed = Slow.
6. Rule 6: If error Z1 and delta error Pd then Pump Speed = Medium.
7. Rule 7: If error Z2 and delta error Nd then Pump Speed = Medium.
8. Rule 8: If error Z2 and delta error Zd then Pump Speed = Medium.
9. Rule 9: If error Z2 and delta error Pd then Pump Speed = Fast.
10. Rule 10: If error Z3 and delta error Nd then Pump Speed = Medium.
11. Rule 11: If error Z3 and delta error Zd then Pump Speed = Fast.
12. Rule 12: If error Z3 and delta error Pd then Pump Speed = Fast.

The final stage is defuzzification, which uses the weighted average method. The result of this defuzzification is an action value used to adjust the pump delay. The weighted average formula is shown in Equation 1:

$$\text{Output} = \frac{\sum \mu(y) \cdot y}{\sum \mu(y)} \quad (1)$$

In this case, y represents the output value obtained from the rule, while $\mu(y)$ indicates the degree of membership calculated using the membership function.

III. Results and Discussion

The result of the system design is a greenhouse prototype equipped with an electrical panel box and several components, such as actuators (pump and LED lights), a watering tank, nozzles and hoses for the watering process, and planting media containers as a place for plants to grow.

i. Results of Soil Moisture Sensor Calibration

The process of calibrating soil moisture sensors aims to ensure that the values detected by the sensor correspond to the actual soil moisture conditions. This process involves comparing the sensor output with a soil moisture measuring device.

Based on the linear regression graph in Figure 10, the equation is obtained as:

$$y = -0.0055x + 140.55 \quad (2)$$

(a)

(b)

Figure 9: Result System Design

Table 2: Soil Moisture Sensor Calibration Data

Soil Moisture (%)	Analog Value
26	20850
59	14778
61	14195
62	13983
70	13287

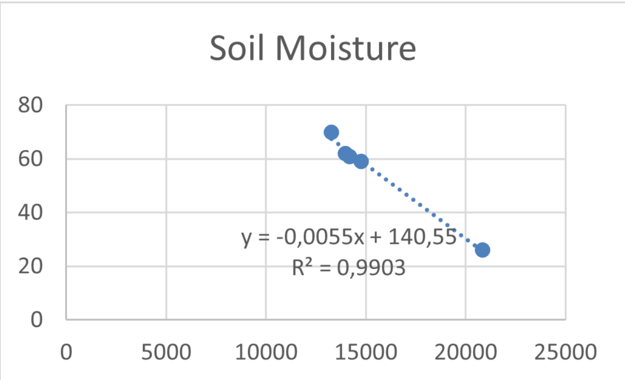


Figure 10: Soil Moisture Linear Regression Graph

where y is the soil moisture (%) and x is the analog value. The coefficient of determination $R^2 = 0.9903$ indicates a very good fit to the data.

ii. Result of Light Intensity Sensor Calibration

This process involves comparing the light intensity sensor output with a reference light intensity measuring device.

The equation for the linear regression is:

$$y = 6.3433x + 831.56 \tag{3}$$

where y is the measured light intensity (lux) and x is the sensor reading. The coefficient of determination $R^2 = 0.9708$ shows a strong fit between sensor data and actual measurements.

Table 3: Light Intensity Sensor Calibration Data

Measuring Instrument	Sensor Value	Accuracy (%)	Error (%)
39	0	100	0
945	166	82.43	17.57
1310	381	70.92	29.08
1151	253	78.02	21.98
1302	330	74.65	25.35
1335	356	73.33	26.67
1360	469	65.51	34.49
1500	569	62.07	37.93
2100	631	69.95	30.05
4041	759	81.22	18.78
4600	869	81.11	18.89
8500	1330	84.35	15.65
8600	1356	84.23	15.77
8760	1398	84.04	15.96
8955	1498	83.27	16.73
9150	1566	82.89	17.11
9200	1637	82.21	17.79
9380	1676	82.13	17.87
9390	1690	82.00	18.00
Average		79.18	20.82

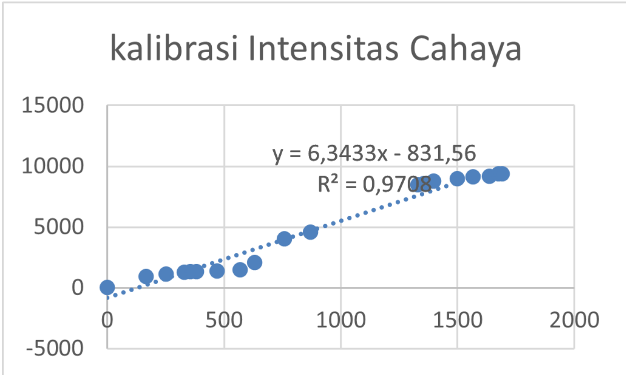


Figure 11: Linear Regression Graph of Light Intensity

iii. Soil Moisture Accuracy Testing Results

Table 4 shows that the soil moisture sensor has a relatively high consistency, with 4 out of 5 samples showing 100% accuracy. One sample shows a significant error likely due to the instability of the manual soil meter device.

iv. Light Intensity Accuracy Testing Results

The process of testing the light intensity sensor involves collecting calibrated output data using the linear regression method with Arduino IDE, then comparing it with the measurement results of the standard measuring instrument shown in Table 5.

After applying the regression function in the Arduino IDE, sensor accuracy significantly improved to 98.15%. Minor deviations are still possible due to placement, angle, reflection, and casing.

Table 4: Soil Moisture Sensor Accuracy Testing

No	Sensor (%)	Analog (ADC)	Volt (V)	Soil Meter (%)	Error (%)	Accuracy (%)
1	60	14600	1.8	58	3.33	96.7
2	67	13384	1.7	67	0.00	100
3	70	12788	1.6	70	0.00	100
4	40	18230	2.3	6	85.00	15
5	69	12829	1.7	69	0.00	100
Average					17.7	82.3

Table 5: Light Intensity Sensor Accuracy Testing

No	Sensor	Measuring Instrument	Error (%)	Accuracy (%)
1	1107	1185	6.58	93.42
2	1513	1431	5.73	94.27
3	2273	2210	2.85	97.15
4	3334	3350	0.48	99.52
5	10209	10200	0.09	99.91
6	10271	10260	0.11	99.89
7	10460	10380	0.77	99.23
8	10481	10402	0.76	99.24
9	16405	16390	0.09	99.91
10	20846	20625	1.07	98.93
Average			1.85	98.15

v. Results of the Fuzzy Logic Pump Speed Test

This test compares fuzzy logic pump output between the Arduino system and MATLAB simulation.

Table 6: Pump Speed Output (Fuzzy)

No	Err	ΔErr	MATLAB (PWM)	Arduino (PWM)	Error (%)	Accuracy (%)
1	5	10	200	200	0	100
2	4	-1	100	150	33.3	67
3	0	0	0	0	0	100
4	-1	-3	0	0	0	100
5	2	0	150	150	0	100
6	1	0	150	150	0	100
7	21	0	230	230	0	100
8	12	0	200	200	0	100
9	1	10	200	200	0	100
10	1	1	150	167	10.2	90
Average					4.35	96

Results show good alignment, with an average error of 4.35% and 96% accuracy. Slight differences may come from rounding and execution environment limitations on Arduino [22].

vi. The Sugeno Fuzzy Logic Control System Response

The fuzzy logic system responds within 6 minutes, achieving stable soil moisture without overshoot. This demonstrates good system responsiveness and control.

vii. Plant Growth Comparison With and Without LED

Tables 8 and 9 show that LED significantly improves plant height (17.12 cm vs 13.65 cm). However, LED treatment delays flowering, while the absence of LED triggers early flower budding in some samples.

Table 7: Results of the Fuzzy Logic System Response

Parameter	Value	Time	Duration
Initial SM (%)	65	–	–
Set Point (%)	70	–	–
Tr (Rise Time)	69%	05:43–05:48	04:31
Ts (Settling Time)	70%	05:42–05:48	05:58
Tp (Peak Time)	70%	05:42–05:48	06:03
Td (Delay Time)	66%	05:42–05:43	01:12
Mp (Max Point)	70%	–	–
Ess (Steady-State Error)	70%	–	–

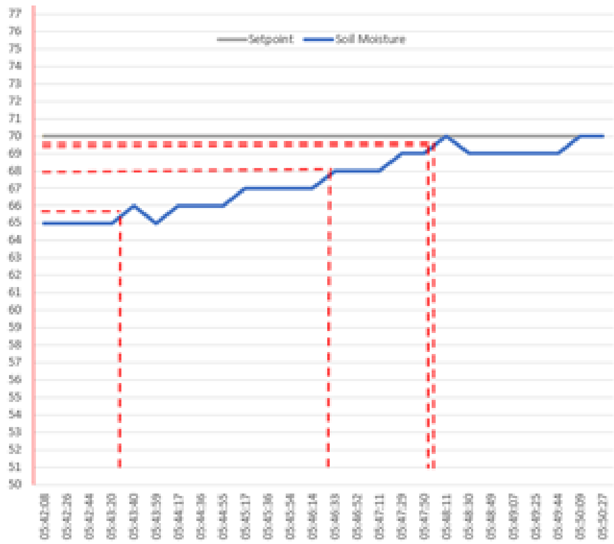


Figure 12: Results of the Fuzzy Logic System Response

Table 8: Plant Height with LED

Test	Min (cm)	Max (cm)	Average (cm)	Flower Bud
1	4	4	4	–
2	8	9	8.4	–
3	10.5	11.5	11	–
4	15	21.5	17.5	–
5	23	35	27.3	–
6	26	44.5	34.5	–
Average	14.42	20.92	17.12	–

Figure 13: Test 1 with LED

Figure 14: Test 1 without LED

Figure 15: Test 6 with LED

viii. Mobile App Testing

The results of testing the mobile application, developed using Kodular and integrated with Firebase as the IoT data communication platform, show that it effectively monitors sensor data and controls the system in real time via the Android platform. The result is shown in

Figure 16: Test 6 without LED

Table 9: Plant Height without LED

Test	Min (cm)	Max (cm)	Average (cm)	Flower Bud
1	4	4	4	–
2	5.5	7	6.2	–
3	9	11	10	✓
4	9	17.5	13.2	✓
5	0	22.5	22.5	✓
6	0	26	26	✓
Average	6.88	14.67	13.65	✓

Figure 17.

Table 10: Mobile App Result

No	Feature	Information	1	2	3	4	5
1	Splash screen	Splash screen for 3s, then proceed to the Login Screen.	✓	✓	✓	✓	✓
2	Screen Login	If login is successful, move to Monitoring; if failed, stay.	✓	✓	✓	✓	✓
3	Monitoring Screen	Real-time data and actuator status display.	✓	✓	✓	✓	✓
4	Control Screen	Options for auto, manual, emergency, reset control.	✓	✓	✓	✓	✓
5	Auto Control	Based on plant phase.	✓	✓	✓	✓	✓
		Based on user needs.	✓	✓	✓	✓	✓
6	Manual Screen	Manual watering, nutrition, and lighting.	✓	✓	✓	✓	✓

Note: (✓) = Functional, (x) = Non-functional

All application features functioned well across

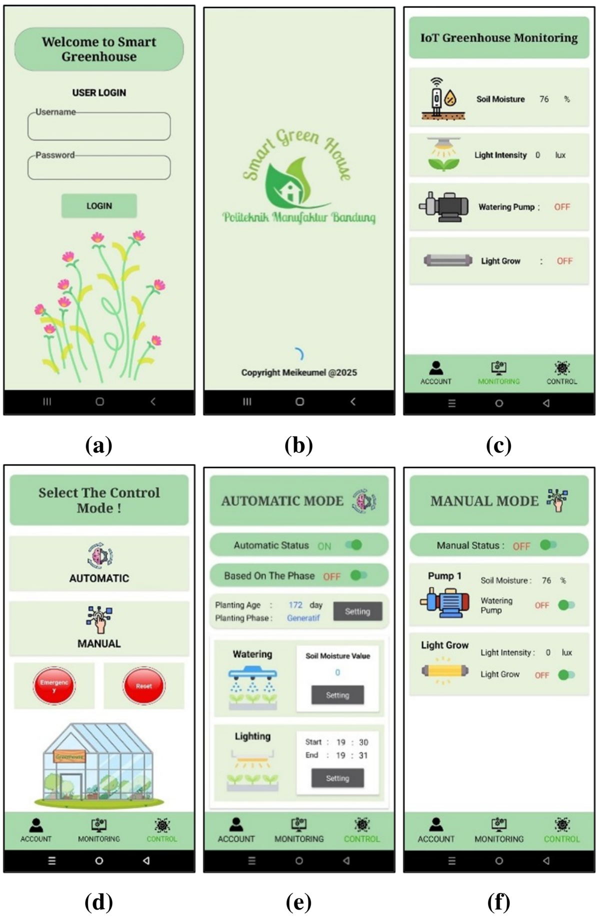


Figure 17: Mobile App result

;

five tests, indicating strong reliability and readiness to support both automatic and manual control systems.

ix. Results of Data Communication Testing

Table 11: Results of Data Communication Testing

No	Distance (km)	Monitoring	Control
1	1	✓	✓
2	3.9	✓	✓
3	4.4	✓	✓
4	5.5	✓	✓
5	5.7	✓	✓
6	13	✓	✓
7	158	✓	✓
8	161	✓	✓

The system demonstrated stable two-way communication for monitoring and control up to 161 km, confirming long-range IoT effectiveness.

IV. Conclusion

This study introduces an integrated Internet of Things (IoT)-based automatic control system for greenhouse chrysanthemum cultivation, combining fuzzy logic for irrigation and time-based lighting regulation. The system aims to enhance environmental control by aligning soil moisture and lighting with the plant's vegetative and generative phases.

Implemented using an ESP32 microcontroller, soil moisture and light intensity sensors, and a Firebase-connected Android application, the system enables real-time monitoring and remote control. Calibration improved sensor accuracy to 82.33% for soil moisture and 98.15% for light intensity. The fuzzy logic controller achieved an average deviation of 4.35% from MATLAB simulations, with the irrigation system demonstrating stable response characteristics—delay of 1 minute 12 seconds, rise time of 4 minutes 31 seconds, and settling time of 6 minutes without overshoot.

Communication remained reliable over distances exceeding 161 km, and LED lighting was found to boost vegetative growth, although it slightly delayed flowering. This research contributes a novel integration of fuzzy logic and IoT for phase-specific environmental control in chrysanthemum cultivation—an area underexplored in prior work. The system's modular design makes it adaptable for different crops and environmental setups. However, its current configuration is optimized for small-scale greenhouses with single-zone control.

Future work should focus on expanding system scalability, incorporating real-time adaptive lighting based on sensor feedback, and testing under varying climatic conditions to validate broader applicability.

Acknowledgment

Thanks are extended to *Pusat Penelitian dan Pengabdian Masyarakat (P3M)* of Bandung Manufacturing Polytechnic for funding this research. Also, to the Control System Laboratory Team and the Production Laboratory, Department of Manufacturing Automation Engineering and Mechatronics, Bandung Manufacturing Polytechnic, for providing very meaningful facilities and technical assistance.

References

[1] D. J. Hannia, R. Oktiansyah, A. Ekaprasetio, A. Putri, and A. Arief, "Pengaruh panjang entres tanaman bunga kertas (bougainvillea spectabilis) dengan metode grafting di uptd balai pengembangan dan produksi benih tanaman pangan," *Unpublished*, 2021.

[2] B. P. S. Indonesia, "Statistik hortikultura 2022," 2023, accessed: 2025-01-06. [Online]. Available: https://www.bps.go.id/id/publication/2023/06/09/03847c5743d8b6cd3f08ab76/statistik-hortikultura-2022.html

[3] D. Qisthi and S. Sitawati, "Pengaruh ekspresi pertumbuhan generatif terhadap krisan (chrysanthemum morifolium) potong tipe spray akibat pencahayaan buatan," *Produksi Tanaman*, vol. 12, no. 1, pp. 56–63, 2024. [Online]. Available: https://doi.org/10.21776/ub.protan.2024.012.01.07

[4] M. Flowers, "Arti bunga krisan: Karakteristik, etimologi dan makna simbolisnya," 2024, accessed: 2024-12-06. [Online]. Available: https://myflowers.family.blog/2024/08/19/arti-bunga-krisan/

[5] N. Sharma *et al.*, "Phytochemicals, therapeutic benefits and applications of chrysanthemum flower: A review," *Heliyon*, vol. 9, no. 10, p. e20232, 2023. [Online]. Available: https://doi.org/10.1016/j.heliyon.2023.e20232

[6] I. G. Udayana *et al.*, "Increasing added value of chrysanthemum through cultivation improvement in agro pudak lestari ornamental plant farmers group," *Asian Journal of Community Services*, vol. 2, no. 10, pp. 869–878, Nov 2023. [Online]. Available: https://doi.org/10.55927/ajcs.v2i10.6615

[7] H. Sujadi and Y. Nurhidayat, "Smart greenhouse monitoring system based on internet of things," *Computer Science*, no. 01, 2019.

[8] S. A. Nuraini, M. Sarosa, and D. Suprianto, "Smart agro system pada budidaya tanaman krisan di daerah nir-wifi menggunakan komunikasi bluetooth."

[9] O. B. Cahyono, M. J. Afroni, B. M. Basuki, and J. M. Haryono, "Abstrak kondisi kelembaban green house sangat penting untuk pembudidayaan bunga krisan agar diperolehnya."

[10] Y. S. Fono, A. B. Setiawan, and D. C. Permatasari, "Monitoring kelembaban tanah dengan menggunakan metode fuzzy sugeno pada bunga krisan berbasis iot," *Prosiding Seminar Nasional SAINS DATA*, vol. 3, no. 1, pp. 26–33, Oct 2023. [Online]. Available: https://doi.org/10.33005/senada.v3i1.61

[11] ——, "Monitoring kelembaban tanah dengan menggunakan metode fuzzy sugeno pada bunga krisan berbasis iot," *Prosiding Seminar Nasional SAINS DATA*, vol. 3, no. 1, pp. 26–33, Oct 2023. [Online]. Available: https://doi.org/10.33005/senada.v3i1.61

[12] K. Firdaus, E. Purbayanti, and E. Fuskhah, "Budidaya dan kualitas pasca panen krisan (chrysanthemum morifolium r.) varietas white fiji akibat konsentrasi giberelin dan mulsa jerami padi," *Jurnal AGRONIDA*, vol. 9, no. 2, pp. 65–74, Oct 2023. [Online]. Available: https://doi.org/10.30997/jag.v9i2.8703

[13] P. M. Syahfitri, W. Mildaryani, and D. Astriani, "Pengaturan pembungaan krisan pot (chrysanthemum morifolium) dengan variasi lama penyinaran lampu," 2025.

[14] N. T. Ledhe, "Analisis pertumbuhan tanaman krisan pada variabel warna cahaya lampu led."

[15] "174160-id-pertumbuhan-vegetatif-dan-generatif-stac.pdf," accessed: Dec. 11, 2024. [Online]. Available: https://media.neliti.com/media/publications/174160-ID-pertumbuhan-vegetatif-dan-generatif-stac.pdf

[16] D. R. T. Dewa and C. Jemima, "Perancangan greenhouse untuk tanaman calathea dengan metode perancangan eksperimen," 2023.

[17] A. Pangestu, U. Latifa, and L. Nurpulaela, "Perancangan sistem monitoring jarak jauh pada smart agriculture system," *Aisyah Journal of Informatics and Electrical Engineering (AJIEE)*, vol. 5, no. 1, pp. 1–11, Feb 2023. [Online]. Available: https://doi.org/10.30604/jti.v5i1.142

[18] Y. Sosmita and R. I. Salam, "Rancang bangun aplikasi mobile untuk pemantauan dan kontrol sistem keamanan pintu rumah berbasis iot," 2024.

[19] D. Septriani, I. Lutfhi, and P. Risma, "Implementasi fuzzy logic metode mamdani pada sistem kontrol penyiram tanaman bawang merah otomatis di prabumulih," Nov 2024. [Online]. Available: https://doi.org/10.5281/ZENODO.13308905

[20] J. R. Pagala, K. Santa, and Q. C. Kainde, "Implementasi fuzzy logic untuk pengaturan kelembapan tanah pada tanaman sawi berbasis internet of things (iot)," *Journal of Innovation in Future Technology (IFTECH)*, vol. 6, no. 2, pp. 174–184, Jul 2024. [Online]. Available: https://doi.org/10.47080/iftech.v6i2.3307

[21] F. Suryatini, W. Purnomo, and R. R. Harlanti, "Sistem kendali penyemaian bersusun pada tanaman hidroponik berbasis logika fuzzy tsukamoto dengan aplikasi blynk," *JITEL Jurnal Ilmiah Telekomunikasi Elektronika dan Listrik Tenaga*, vol. 3, no. 1, pp. 37–46, Mar 2023. [Online]. Available: https://doi.org/10.35313/jitel.v3.i1.2023.37-46

[22] N. M. A. Ghani, A. Othman, A. A. A. Hashim, and A. N. K. Nasir, "Comparative analysis of pid and fuzzy logic controllers for position control in double-link robotic manipulators," *Journal of Intelligent Systems and Control*, vol. 2, no. 4, pp. 183–196, Nov 2023. [Online]. Available: https://doi.org/10.56578/jisc020401