The 2nd International Conference on Multidisciplinary Engineering
(2nd ICOMDEN 2024)

The 2nd International Conference on Multidisciplinary Engineering: 00077 (2024) **https://doi.org/10.29103/icomden.v2.xxxx**
Volume 2, 2024
eISSN: xxxx-xxxx
Research Original Article

Full Automation and Control System Based on IoT in a Greenhouse (Case Study: Faculty of Agriculture, Malikussaleh University

M Ishlah Buana Angkasa✉[1] **Riza Tjut Adek**[2] **Said Fadlan Anshari**[3]
[1]Universitas Malikussaleh, Bukit Indah, Lhokseumawe, 24355, Indonesia, muhammad.200170170@mhs.unimal.ac.id
[2]Universitas Malikussaleh, Bukit Indah, Lhokseumawe, 24355, Indonesia, rizal@unimal.ac.id
[3]Universitas Malikussaleh, Bukit Indah, Lhokseumawe, 24355, Indonesia, saidfadlan@unimal.ac.id
✉Corresponding Author: muhammad.200170170@mhs.unimal.ac.id | **Phone: +6289526619903**

Abstract
This study aims to develop a full automation and control system based on the Internet of Things (IoT), implemented in a greenhouse to support real-time monitoring of temperature, soil moisture, and water levels in the tank. The system is designed using the ESP32-WROOM microcontroller as the core for data communication with various sensors, including the DHT22 sensor for air temperature and humidity, a soil moisture sensor for soil moisture, and a JSN-SR04T sensor for water level. The developed system connects to Firebase as a cloud data platform, enabling remote monitoring via a specially designed mobile application. Testing shows that the system works efficiently in supporting automated plant growth, reducing manual intervention, and increasing productivity. This system allows students and faculty in the Faculty of Agriculture at Malikussaleh University to more easily conduct research and teaching activities related to modern agricultural technology.
Keywords: *Greenhouse, IoT, Microcontroller, Firebase, ESP32-WROOM.*

Introduction

Agriculture plays a strategic role in meeting global food needs but faces various challenges, such as climate change, limited water resources, and the need for more efficient methods. The greenhouse, as a controlled cultivation system, offers a solution by enabling plant growth in a manageable environment. IoT technology, which utilizes device connections over the internet, provides highly relevant solutions for automated monitoring and control in the context of modern agriculture [1].

However, most existing greenhouse management systems are still manually managed, resulting in inefficiencies in time and labor and the risk of human error [2]. Therefore, this research aims to develop an IoT automation system connected to a mobile application via Firebase, which not only provides automatic control but also real-time access to greenhouse environmental data.

This IoT-based automation system is expected not only to increase crop productivity but also to facilitate academics in conducting research in modern agriculture. By providing accurate and detailed environmental data, this system enables more precise control and management, essential for supporting plant growth and health [3].

Problem Statement

While greenhouse farming has been instrumental in modern agriculture, manual management of environmental parameters such as water levels, soil moisture, and temperature remains inefficient and prone to errors. The need for a more precise and automated system to handle these factors is evident. This research seeks to address the following questions:

a) How can temperature, soil moisture, and water levels be effectively monitored and controlled in a greenhouse using IoT technology?
b) How can IoT technology be integrated into an agricultural system to enhance greenhouse operations and improve plant growth conditions?

Research Objective

a) How can IoT be implemented to monitor and control temperature, soil moisture, and water level conditions in a greenhouse automatically?

b) How can a system be designed to display real-time data and enable remote control through a mobile application?

This research aims to develop an automation system that can support agricultural productivity by monitoring and controlling environmental conditions in a greenhouse based on IoT connected to Firebase, allowing real-time remote access and monitoring.

Literature Review

IoT technology has become one of the most influential innovations in automating various sectors, including agriculture. This research utilizes the ESP32-WROOM microcontroller and the Firebase platform to provide remote monitoring services via an application developed in Kodular. The use of rule-based control in this study also offers a simple yet efficient solution for activating or deactivating devices according to environmental conditions. This contributes to automated and real-time environmental monitoring in greenhouses supported by IoT [4].

Research Methodology

This research was conducted using a 50x25 cm greenhouse prototype. The system design involves several key components and implementation stages as follows:

System Design

The system uses the ESP32-WROOM microcontroller as a control center, connecting various sensors to Firebase via Wi-Fi. The sensors used include:

- DHT22 for air temperature and humidity.
- Soil Moisture Sensor for soil moisture.
- JSN-SR04T for measuring water levels in the tank. Sensor data is sent to Firebase, which can be accessed by the mobile application via the internet. The system is also equipped with actuators, such as a submersible water pump and cooling fan, which activate or deactivate based on the received environmental data [5].

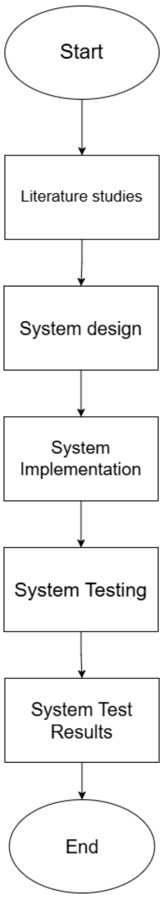

Figure 1 Flowchart of Research Steps

Data Collection

Primary data collected include environmental parameters relevant to plant growth:

- Air Temperature and Humidity: Generated by the DHT22 sensor inside the greenhouse. This data is essential to maintain optimal plant conditions.
- Soil Moisture: Measured using a soil moisture sensor that converts soil resistance into a moisture percentage, enabling automatic watering based on actual moisture levels [6].
- Water Level: The JSN-SR04T sensor measures the water distance from the sensor's position above the tank. This data determines when the water pump should be activated.

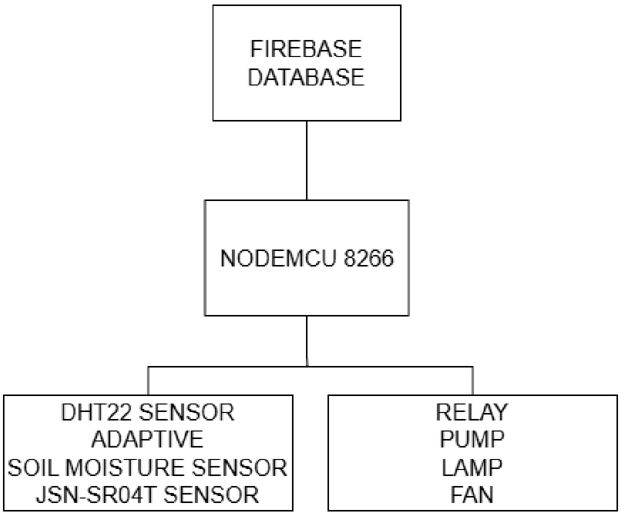

Figure 2 Collection Step

Rule-Based Control

The system uses a rule-based control method, where each environmental parameter, such as temperature, air humidity, and soil moisture, has predetermined thresholds according to plant needs in the greenhouse. If the environmental parameters are outside the ideal limits, the system automatically activates or deactivates relevant actuators, such as fans, heaters, humidifiers, or water pumps [7]. The system controls conditions based on optimal parameters, for example:

- Temperature: If air temperature exceeds 28°C, the cooling fan will activate to lower the temperature. If the temperature drops below 24°C, the heater will activate.
- Air Humidity: The humidifier will activate if humidity is less than 60%, while the exhaust fan will turn on if humidity exceeds 80%.
- Soil Moisture: The water pump will activate when soil moisture falls below the required level.

With this rule-based control, optimal growing conditions in the greenhouse can be maintained without significant manual intervention. The table below shows the rules applied in the system:

Table 1. Ruled-Based for Air Temperature and Humidity

Parameter	Ideal Boundary	Control Rules
Air Temperature	24°C – 28°C 24°C – 28°C	If the temperature is > 28°C, the system activates the cooling fan to lower the temperature. If the temperature is < 24°C, the heater is turned on to raise the temperature.
Humidity	60% – 80% 60% – 80%	If the air humidity is < 60%, the humidifier will be activated to increase the humidity. If the air humidity is > 80%, the exhaust fan will be activated to reduce the humidity.

Table 2. Ruled-Based untuk Kelembapan Tanah Berdasarkan Jenis Tanaman

Plants	Ideal Temperature	Ideal Soil Moisture	Control Rules
Tomatoes	22°C – 26°C	50% – 60%	If the soil temperature or humidity goes out of the ideal limits, the system will adjust according to the relevant rules.
Melon	25°C – 30°C	40% – 50%	The system will control the temperature and humidity of the soil according to the needs of the melon plants.
Soybeans	24°C – 28°C	45% – 55%	Soybeans will be monitored using these temperature and humidity limits to maintain an optimal growing environment.
Mushrooms	18°C – 22°C	60% – 70%	If the humidity or temperature goes out of the optimal range, the system will activate the appropriate device (fan, humidifier, or water pump) to maintain ideal conditions.

Mobile Application

The mobile application is designed in Kodular, providing users with access to monitor real-time data from Firebase. Additionally, the application allows users to manually adjust settings if needed. The design is user-friendly, allowing users easy access to the necessary information without technical barriers [8].

Results and Discussion

Automation System Implementation

The IoT-based automation system was successfully implemented in the greenhouse prototype. The ESP32-WROOM functions optimally as a control center, sending sensor data to Firebase and displaying real-time data via the mobile application. Each device or actuator in the system operates automatically according to rule-based control [9].

Sensor Testing

- Water Level Sensor (JSN-SR04T): This sensor was tested at various water levels. The results show high accuracy in water distance measurement with an error tolerance of 2 mm, ensuring that the water tank remains within optimal limits.
- Soil Moisture Sensor: This sensor responds quickly and accurately under various soil conditions, with a measurement range of up to 100%. This data is useful for maintaining optimal soil moisture according to plant needs.
- DHT22 Sensor: The DHT22 sensor was tested by comparing its results with a manual measuring device. The data shows high consistency, with an accuracy rate above 95% for air temperature and humidity [10].

Rule-Based Control

The implemented rule-based control system allows devices to operate automatically according to the measured conditions. The system activates or deactivates devices, such as the water pump, cooling fan, and humidifier, when environmental parameters exceed optimal thresholds. This system has been shown to reduce manual intervention, improve energy efficiency, and maintain optimal greenhouse conditions.

Monitoring via Mobile Application

The mobile application designed in Kodular provides user-friendly access to data from Firebase. The data is displayed in graph form and numerical indicators for temperature, humidity, and water level. The notification feature alerts users of significant changes in greenhouse conditions, enabling a quick response.

Figure 3 Mobile View Monitoring

Conclusion

This research successfully developed an IoT-based automation system for monitoring and controlling greenhouse conditions. The system enables real-time monitoring of temperature, soil moisture, and water levels, providing automatic control that supports plant growth. Implementing IoT technology with Firebase as a cloud data platform makes it easier for users to monitor and manage plants remotely via the mobile application.

With these results, the developed system is expected to be applied on a larger scale in agricultural environments or for further research related to automated plant management.

Suggestions

- Field Testing: Conduct trials on a larger greenhouse scale or in complex real-world conditions to ensure system effectiveness under diverse circumstances.
- Machine Learning Integration: Integrate the system with machine learning algorithms to predict environmental conditions based on historical data patterns, aiding in optimizing automatic control.
- IoT and Big Data Combination: Consider integrating with big data technology to store long-term environmental data, which can be used for trend analysis and continuous system improvement.

Acknowledgments

The authors express their deepest gratitude to everyone who has provided support and guidance during the preparation of this research. Special thanks to Mr. Rizal Tjut Adek, the main supervisor, and Mr. Said Fadlan Anshari, the co-supervisor, for their invaluable input and consistent support throughout the research and writing process. We also extend our gratitude to Malikussaleh University for the opportunities and facilities provided during this study. Thanks to my friends for their cooperation and contributions to data collection and analysis, and to my family for their moral support and motivation. Lastly, the authors are grateful to all those who contributed to this research, directly or indirectly, with their inspiration and encouragement. We hope this study benefits the advancement of science.

References (11pt, Book Antiqua)

[1] Chhipa, H., 2017. Nanofertilizers and nanopesticides for agriculture. *Environmental chemistry letters*, *15*, pp.15-22.

[2] Herzog, H., Eliasson, B. and Kaarstad, O., 2000. Capturing greenhouse gases. *Scientific American*, *282*(2), pp.72-79.

[3] Adek, R.T., Ula, M., Mulaesyi, S. and Juhri, M.B., 2022, December. Home Surveillance System Based on Internet of Things and Thermal Sensors. In *Proceedings of Malikussaleh International Conference on Multidisciplinary Studies (MICoMS)* (Vol. 3, pp. 00028-00028).

[4] Babiuch, M., Foltýnek, P. and Smutný, P., 2019, May. Using the ESP32 microcontroller for data processing. In *2019 20th International Carpathian Control Conference (ICCC)* (pp. 1-6). IEEE.

[5] Apsari, G.H.I., Pramono, S. and Zen, N.A., 2022. IMPLEMENTATION OF LINIER REGRESSIONUSING THE JSN-SR04T SENSOR FOR THE MONITORING WATER LEVEL IN WATER TANKS THROUGH ANTARES PLATFORM. *Journal of Electronic and Electrical Power Applications*, *2*(2), pp.123-129.Madakam, S., Ramaswamy, R., & Tripathi, S. (2015). Internet of Things (IoT): A literature review. *Journal of Computer and Communications*, *3*(5), 164-173.

[6] Kizito, F., Campbell, C.S., Campbell, G.S., Cobos, D.R., Teare, B.L., Carter, B. and Hopmans, J.W., 2008. Frequency, electrical conductivity and temperature analysis of a low-cost capacitance soil moisture sensor. *Journal of Hydrology*, *352*(3-4), pp.367-378.

[7] Bernard, J.A., 1988. Use of a rule-based system for process control. *IEEE Control Systems Magazine*, *8*(5), pp.3-13.

[8] Mavropoulou, E., 2021. Platforms for mobile application development for educational purposes. In *ICERI2021 Proceedings* (pp. 9881-9889). IATED.

[9] Li, W.J., Yen, C., Lin, Y.S., Tung, S.C. and Huang, S., 2018, February. JustIoT Internet of Things based on the Firebase real-time database. In 2018 IEEE International Conference on Smart Manufacturing, Industrial & Logistics Engineering (SMILE) (pp. 43-47). IEEE.

[10] Koestoer, R.A., Pancasaputra, N., Roihan, I. and Harinaldi, H., 2019, January. A simple calibration methods of relative humidity sensor DHT22 for tropical climates based on Arduino data acquisition system. In AIP Conference Proceedings (Vol. 2062, No. 1). AIP Publishing.