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Design and Construction of an Internet of Things (IoT)-Based Smart Garden System

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Abstract: The use of the Internet of Things is currently very useful for the plantation sector, especially mustard greens. The Smart Garden System is still not widely found on plantation land. Smart Garden comes from English which means garden or smart garden, which is a system design created to make work in plantations easier. The aim of making this tool is to help in managing the plants, apart from helping in managing the plants, this Smart Garden can also be used to measure the humidity/air content in the soil, because some people who are cultivating do not know/cannot distinguish which soil is good for certain crops are planted and which are not, resulting in many crops failing to harvest and being detrimental because they wither and die. So it is hoped that this smart garden system can help many farmers in maintaining soil moisture conditions and can minimize damage to plants. "Smart Garden System" Refers to the concept of technology integration in garden or agricultural management to increase efficiency, productivity and loss. This Smart Garden System uses an ESP32 Microcontroller as data processing and control for Soil hygrometer, LED, 16x2 LCD, Water Washer and other components.

Keywords: Smart Garden; ESP32 Microcontroller; Soil Hygrometer; LED;Buzzer

INTRODUCTION

Technological developments in the Industry 4.0 era have significantly impacted various aspects of human life, including the agricultural and plantation sectors. Advances in information technology, readily accessible from various parts of the world, have led to the emergence of the Internet of Things (IoT), a technology that enables intelligent connectivity between devices to interact with each other, collect data, perform analysis, and automatically control systems based on the information received (Yudhanto & Aziz, 2020).

The application of IoT technology has expanded into various fields, including plantations. In this context, IoT plays a crucial role in crop monitoring systems, such as real-time monitoring of soil conditions, air temperature, humidity, and acidity levels. This system can assist farmers in monitoring and making data-driven decisions. However, in practice, monitoring activities in the plantation sector are still largely manual, particularly in fertilization, watering, and soil pH monitoring, which are not routinely performed. This situation results in a lack of accurate information regarding plant nutrient requirements (Randy & Febriyansyah,2022).

Soil water content affects organic carbon levels and soil acidity (pH). Soil that is too acidic can inhibit nutrient absorption and negatively affect plant growth (Yunia & Wardiyati, 2020). This condition shows the importance of applying IoT-based technology for automatic soil condition monitoring and management.

Several studies support the development of smart agriculture systems. Anwar et al. (2020) developed a soil nutrient detection system based on color and moisture using the Naïve Bayes method. Meanwhile, Sari et al. (2021) designed a digital soil pH measuring system using Arduino Uno technology. These studies become the basis for developing a more effective automated soil pH monitoring and nutrient control system.

The system in this research uses a semiconductor-based soil pH sensor integrated with an Arduino Uno microcontroller to measure soil acidity. Measurement data is transmitted via the internet and displayed on a Liquid Crystal Display (LCD) and a smartphone. When the soil pH is detected at a low level, the system automatically activates a pump to distribute NaOH solution to raise soil pH to normal levels. When the soil pH is within the ideal range, the pump will stop automatically (Sari et al., 2021; Anwar et al., 2020).

This system provides advantages over previous research, namely the integration of sensors, microcontrollers, and IoT-based applications capable of displaying real-time monitoring results through a smartphone interface. It allows users to remotely monitor soil conditions and optimize nutrient and water management according to plant needs (Romli et al., 2021; Darmawan et al., 2022).

This IoT-based smart garden system is expected to increase the efficiency of plant care, especially in determining watering schedules and adjusting soil acidity levels according to plant conditions. Therefore, this research focuses on the design and testing of an IoT-based smart garden system as a form of innovation that supports the digitalization of the modern agricultural sector.

LITERATURE REVIEW

Technological developments in the Industry 4.0 era have driven the implementation of the Internet of Things (IoT) in various fields, including agriculture. According to Yudhanto and Aziz (2020), IoT is a technology that enables connectivity between devices to automatically collect, transmit, and analyze data. Buyya et al. (2020) emphasize that IoT integrates hardware, networks, and data analytics to create efficient systems.

In the agricultural sector, IoT is applied through the concept of smart agriculture to monitor plant environmental conditions in real time. Romli et al. (2021) developed an IoT-based smart garden system that can regulate automatic watering, while Darmawan et al. (2022) applied similar technology to intelligently control plant growth. Chabir and Kunang (2020) also demonstrated the effectiveness of microcontrollers in regulating watering based on soil moisture data.

Previous research supports the use of sensors and microcontrollers in smart garden systems. Sari et al. (2021) designed an Arduino Uno-based soil pH meter, while Anwar et al. (2020) used a TCS3200 sensor to detect soil nutrients through color analysis. Wijayanti et al. (2020) and Rifaini et al. (2021) added that the ESP32 module is effective in IoT data transmission due to its integrated Wi-Fi and Bluetooth connectivity.

Randy and Febriyansyah (2022) and Retno Devita et al. (2021) demonstrated that IoT systems can improve the efficiency of plant growth monitoring and environmental control. Furthermore, research by Yunia Rachmawati and Wardiyati (2020) emphasized the importance of soil pH regulation for horticultural plant growth.

From these various studies, it can be concluded that the application of IoT in agriculture improves efficiency, environmental monitoring, and resource utilization. However, a more integrated and real-time system is still needed. Therefore, this research focuses on the design of an IoT-based smart garden system capable of automatically monitoring soil pH and moisture and displaying data via smartphone.

METHOD

3.1 Type and Approaches of Research

This research uses experimental and systems engineering (research and development) methods, with an applied quantitative approach. The focus of the research is to design and implement an Internet of Things (IoT)-based smart garden system capable of monitoring soil pH and moisture in real time.

3.2 System Design

The smart garden system consists of three main parts: (1) hardware, (2) software, and (3) IoT connectivity. The hardware includes a soil pH sensor and a moisture sensor (soil hygrometer), an Arduino Uno microcontroller, an ESP32 module as a network connector, and an automatic water pump and LED indicators. The software is designed using the Arduino IDE programming language to read and process sensor data.

The IoT connectivity system uses an ESP32 Wi-Fi module that sends data to a web-based platform or smartphone app to display monitoring results in real-time.

3.3 System Workflow

Data obtained by the pH and humidity sensors is sent to the microcontroller for processing. The readings are compared to predetermined thresholds, If the pH is <30%, the system activates the pump to supply a base solution (NaOH) to neutralize the soil. If the pH is within the normal range (30-50%), the pump will automatically stop. The measurement results data are displayed on the LCD and smartphone application.

3.4 Research Stages

The research was conducted through the following stages:

a. System requirements analysis – identifying sensor, hardware, and software requirements.
b. System design – creating an electronic circuit design and system flowchart.
c. System implementation – assembling the hardware and programming the microcontroller.
d. System testing – verifying the accuracy of sensor readings and the effectiveness of automated watering and pH control.

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Result evaluation – analyzing test result data to assess system reliability and stability.

3.5 Location and Research Objects

The research was conducted in an electronics laboratory using mustard greens (Brassica juncea) as the experimental subjects. The system was tested to monitor changes in soil pH and moisture during the plant's growth period.

RESULT

3.1. Software Design

A block diagram is a basic description of system hardware design which contains the working sequence of the system to be designed. Each block diagram has its own function. The block diagram of the designed system is as shown in the following figure:

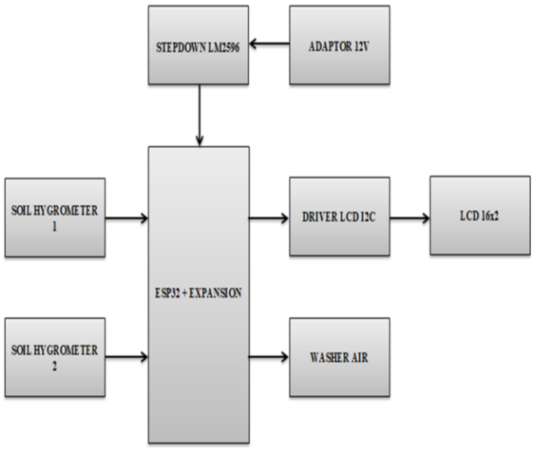

Figure 1. Tool Block Diagram

3.2.System Design/ Architecture

This system was designed using Fritzing software to test the tool before prototyping it. The diagram of the smart garden system design based on the Internet of Things is shown below:

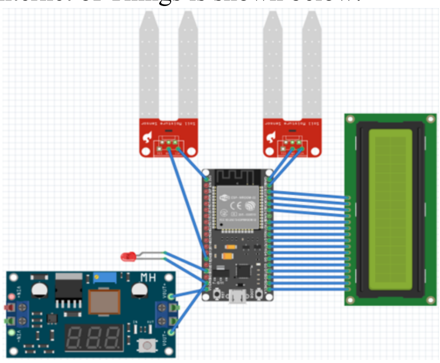

Figure 2. Schematic of the smart garden system

The following are some descriptions of the path directions in the smart garden system scheme:

1. Input

a. Soil hygrometer 1: the VCC soil hygrometer pin is connected to the G23 ESP32 pin, the soil hygrometer GND pin is connected to the ESP32 GND.

b. Stepdown LM2596: The VOUT + pin is connected to the V5 pin of the ESP32 and the VOUT – pin is connected to the GND pin of the ESP32.

2. Output

a. Led: The LED VCC pin is connected to the ESP32 G13 pin and the LED GND pin is connected to the ESP32 GND pin.

b. LCD 16x2: DB0-DB7 pins are connected to G14-G21 pins.

c. Website via IP Address.

Figure 3. Smart garden System view

3.3. System Flowchart

The design phase is the step in determining how a system will operate. The manufacturing flow of the designed system is shown in the following figure:

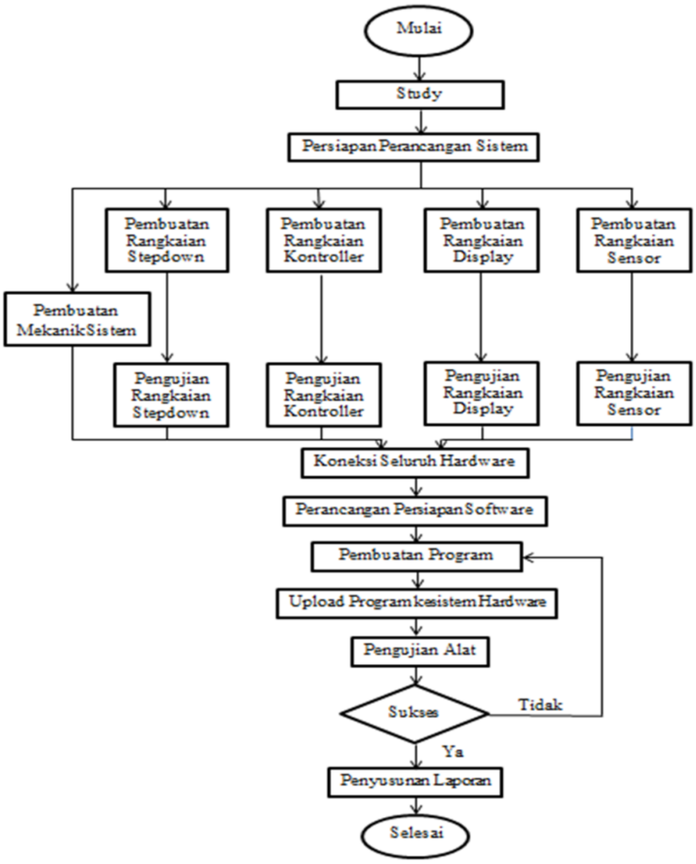

Figure 4. System Flowchart

3.4. Final Design Result

After several design stages were carried out, starting from system analysis, system design, and system testing, as well as the overall working system of the tool, both software and hardware, which have been tested in

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the robotics lab of the Indonesian Institute of Technology and Business, and can function as expected, with the following results:

a. The Soil Hygrometer is designed to function as a soil moisture meter.
b. The water washer designed functions to channel water to the mustard plants
c. The 16x2 LCD is designed to function as a display for sensor data reading results.
d. The buzzer is designed to function as a warning indicator if the water humidity is very low
e. LED that functions as a marker for low soil moisture.
f. The LM2596 stepdown functions to reduce DC voltage.
g. Sending data via application with IP Address

The software system design on Arduino functions to convert sensor readings. The following displays the test results of the Internet of Things-based smart garden system:

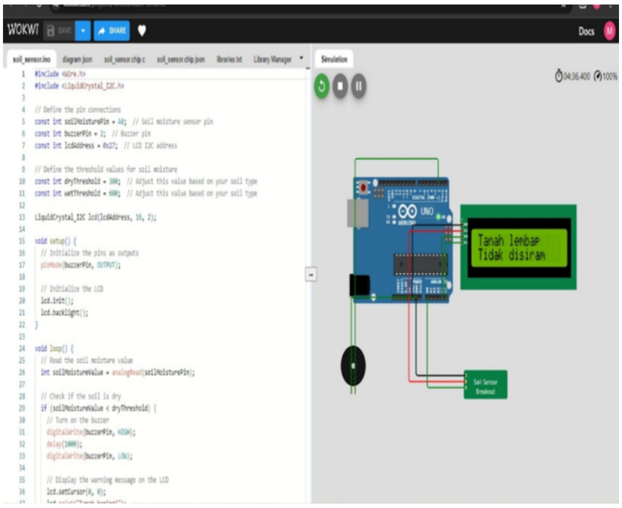

Figure 5. Simulation of system test results

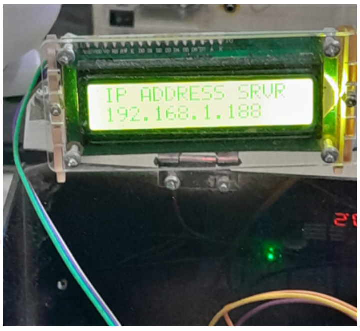

Figure 6. IP Address Test results

Figure 7. Resluts of dry soil testing on a mobile phone

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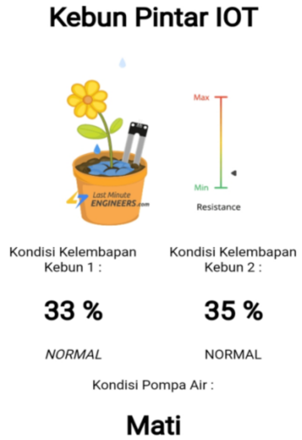

Figure 8. Results of normal soil testing on a mobile phone

In figures 7 and 8 we can see how the display on the cellphone displays information related to the garden that has been connected using the IP Address that is on the LCD screen.

DISCUSSIONS

This section explains how an Internet of Things-based Smart Garden System Design works, as follows:

a. This system is equipped with a soil hygrometer sensor as an input for measuring soil moisture.
b. It uses an LM2596 stepdown converter to reduce the DC voltage.
c. The ESP32 microcontroller, as the control center, processes the sensor readings and sends them to the outputs in the form of an LCD, LED, website, and washer.
d. The 16x2 LCD displays the sensor readings.
e. If the soil moisture is <10%, the soil is detected as very dry. The system sends a command to the water pump to automatically water it.
f. If the soil moisture is <30%, the soil is detected as dry. The system sends a command to the water pump to automatically water it.
g. If the soil moisture is <50%, the soil is detected as normal.
h. If the soil moisture is <80%, the soil is detected as damp.
i. If the soil moisture is <100%, the soil is detected as very damp.
j. The system sends sensor reading data via the application by typing the IP address.

Based on the results and discussion above, the advantages and disadvantages of the Internet of Things-Based Smart Garden System Design are as follows:

1. System Advantages
a. Enables real-time plant monitoring through connected sensors, such as soil moisture sensors.
b. Can automatically distribute water based on sensor readings, minimizing prolonged drought.
c. Uses water efficiently based on actual plant needs, reducing waste and maintaining soil moisture.
d. Can provide early warnings of low soil moisture, enabling rapid preventative action.
e. By monitoring plant conditions more closely, this system can help increase crop yields by ensuring optimal crop conditions.
2. System Disadvantages
a. High initial costs for building IoT infrastructure, including sensors and communication systems, can be quite expensive.
b. Assembling and integrating various IoT components (sensors, software, and networks) requires high technical expertise.
c. System failures or disruptions can disrupt smart garden operations, requiring regular maintenance and care.
d. Potential security risks associated with collecting, transmitting, and storing data from connected sensors require robust security systems to protect sensitive information.

CONCLUSION

The conclusion of the study, entitled Design and Construction of an Internet of Things-Based Smart Garden System, shows that the designed system is capable of directly monitoring plant conditions and automatically regulating air distribution based on the obtained sensor data. This implementation system has proven effective in optimizing air use, reducing waste, and maintaining stable soil moisture. Furthermore, the system's ability to carefully monitor plant conditions allows for early warning when soil moisture levels are low, thus supporting more efficient and sustainable plant care.

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