Developing A Smart Farming Greenhouse Monitoring System based on Internet of Things Technology

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ABSTRACT

This research aims to develop agricultural digitalization through the Smart Farming Model, using Internet of Things (IoT) technology, to assist in monitoring plants, so that the growth and yields of horticultural crops are optimal. Building a greenhouse is very necessary so that the living environment for horticultural plants can be regulated and monitored. The research stages carried out were preliminary studies, analysis of smart farming system model needs, system model design, model development, making smart farming system prototypes, system testing and evaluation of system testing results. The variables measured are room temperature, room humidity and pH of water for watering plants. The research results show that temperature measurements in the greenhouse use a DHT11 sensor (30.86 degrees Celsius) and a thermometer (30.72 degrees Celcius), so there is a difference of 1%. The test results for testing the pH value of water using the pH-4502c sensor were 6.67. Then the results of humidity testing using a capacitive soil moisture sensor were 97.5%. Furthermore, the development of a smart farming greenhouse monitoring system uses an Android application and can be accessed in real time.

Keywords: *Smart Farming, Greenhouse, Monitoring System, Internet of Things, Android.*

1. INTRODUCTION

Agriculture is an important sector that supports the continuation of human civilization everywhere [1], including in Indonesia, which is known as an agricultural country, where the majority of the population depends on the agricultural sector. Indonesia's Gross Domestic Income (GDP) is also supported by the agricultural sector. In recent years, this income has decreased because agricultural productivity is considered sluggish due to various factors. One of them is the lack of interest of successors in the agricultural sector. The use of technology is also relatively low so practices are still carried out using conventional methods. The concept of agricultural development in the Industrial Revolution 4.0 campaign is also considered to be a solution [2]. Agricultural Revolution 4.0 was designed by involving digital technology in the development process [3].

The Covid-19 pandemic has accelerated the pace of change from traditional to digital [4]. The agricultural digitalization process for various crop commodities needs to be carried out immediately to adapt to developments in information technology [5]. The agricultural commodities favoured are food and horticultural crops [6]. During the Covid-19 pandemic, there was an increase in demand for horticultural commodities [7]. Horticultural commodities grew 7.85 percent due to demand for fruits and vegetables. In 2021, the Ministry of Agriculture will continue to increase horticultural products, especially to meet domestic needs. There are 3 main strategies carried out by the Ministry of Agriculture for the development of horticulture 2021-2024, namely the development of Horticultural Villages, the growth of Horticultural MSMEs, and the digitalization of agriculture through the development of information systems.

Internet of Things (IoT) and relevant technologies [8] have a significant impact on smart agriculture as a major sub-domain in agriculture [9],[10]. Modern technology supports data collection from IoT devices through several agricultural processes [11]. The extensive amount of smart farming data collected can be used for everyday

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decision making and analysis such as yield prediction, growth analysis, quality maintenance, animal and aquaculture, and livestock management. Smart Farming can be defined with a narrow concept or a broad concept [12]. The narrow definition of smart agriculture refers to agriculture where ICT technology is applied in both greenhouses and gardens. The use of smart farming is an innovative approach that can increase the productivity and quality of agricultural products even while using less labor, energy and fertilizer than before [13]. The broad concept of smart agriculture is the digitalization of agriculture in various ways to achieve innovation in all industries related to agriculture, from agricultural production to distribution, consumption, tourism and rural life [14].

Research conducted by Moon, et al. [15], researched that the volume of data collected by various IoT sensors used in Smart Farming applications is increasing, thus requiring large data storage and processing. for agricultural applications is a big challenge. Specifically, this study applies three transformation-based lossy compression mechanisms to five weather data sets collected from different sampling granularity of IoT weather stations. The results show that there is a strong positive correlation between the concentrated energy of the transformed coefficients and the compression ratio and data quality. Then, this research shows that sampling details also affect predictions and data compression ratios. Research conducted by Al-Ali, et al. [16], about the use of IoT for Smart Farming with a research focus on smart irrigation systems. This research uses solar cell panels as an energy source in developing a smart irrigation system. Distributed solar energy resources can be operated, monitored and controlled remotely. The design of IoT-based solar energy systems for smart irrigation is critical for regions around the world, which face water and electricity scarcity. The proposed system uses a single board system-on-a-chip controller, which has WiFi connectivity, and connection to solar cells to provide the required power. The controller reads the soil moisture, air humidity, and temperature sensors, then issues actuation commands according to the signals to operate the irrigation pump.

This research aims to develop agricultural digitalization through the Smart Farming Model, using Internet of Things (IoT) technology, to assist in monitoring plants, so that the growth and yields of horticultural crops are optimal. Building a greenhouse is very necessary so that the living environment for horticultural plants can be regulated and monitored. The novelty and contribution to science in this research is that through the development of the Smart Farming model it will help optimize agriculture and horticultural crop production. Agricultural processes are carried out by utilizing information technology, such as the internet of things (IoT), the use of sensors and the existence of web and Android-based monitoring systems.

2. METHODS

The research method used is the research and development method, with research stages including: literature study, survey and observation, system model design, hardware and software system requirements analysis, system prototype creation and system testing.

2.1. Hardware System Design

The smart farming system model is presented in Figure 1.

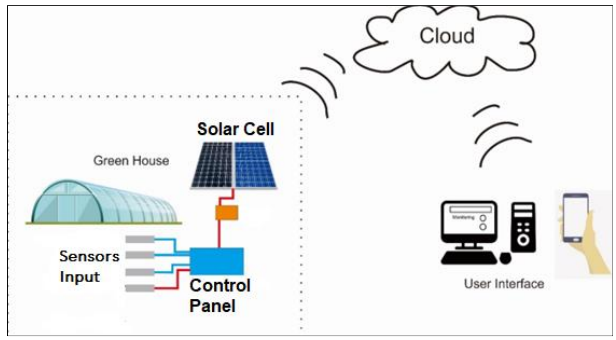

Figure 1 Smart Farming Model

Through the development of this Smart Farming model, agricultural processes are carried out by utilizing internet of things (IoT) technology, the use of sensors and an Android application-based monitoring system that can be monitored online and in real time. The variables measured are room temperature, room humidity, soil moisture and pH of the water used for watering plants.

The stages of developing a smart farming greenhouse monitoring system are as follows in Figure 2.

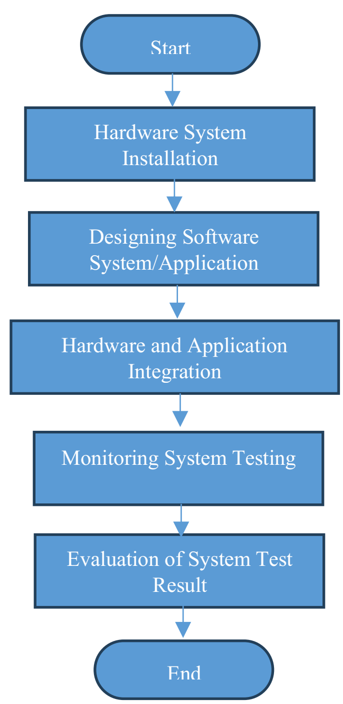

Figure 2 Research Stages Flow Chart

Wiring diagram systems in Figure 3 are made to make it easier to arrange hardware device circuits, so that the hardware system is arranged properly.

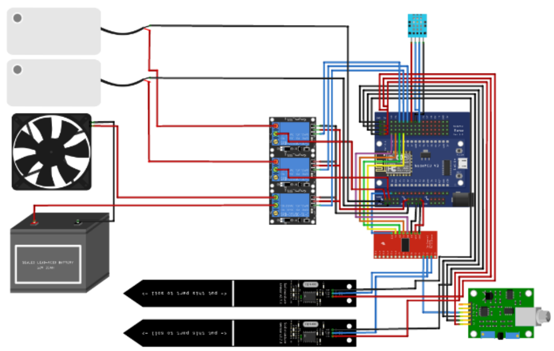

Figure 3 Wiring Diagram System

The tools and materials used in this research include batteries, water pump, relay, NodeMcu Esp8266, Arduino Uno microcontroller, Capacitive Soil Moisture Sensor, fan, Temperature Sensor DHT11, pH Sensor, and AB Mix liquid fertilizer. The design of the following tool has been arranged according to research needs, as can be seen in the picture, there is an ESP8266, soil moisture sensor, pH sensor, breadboard, fan, 9v battery, water pump, DHT11 and also a relay. The circuit in the picture above has 6 relays, and the implementation in this research uses relays that have been formed into 6 rows and are not separated. Then for the battery it is enough to use 9 Volts for each relay to provide a voltage of 5V to the fan and water pump.

2.2. Software and Application System Design

Arduino IDE is the most important material in programming, because a microcontroller, electronic devices and sensors will not work until commands are given and written in Arduino IDE. This software, which uses the CC++ programming language, will act as a compiler to determine whether the program written is correct or error. Then, after the program is declared correct, the next role is to upload it to the microcontroller where the program will be saved and executed according to the required electronic devices, as shown in Figure 4.

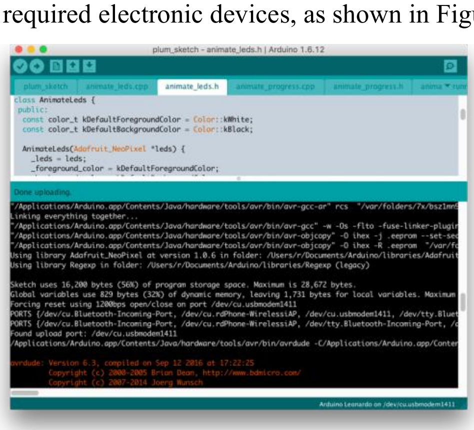

Figure 4 Arduino IDE

To design software systems and applications, there are several steps as follows.

a) The first thing to do is installation, the installation here is to connect several sensors to the ESP8266 according to the required pins and connect the EPS8266 to WiFi so it can connect to the internet.

b) Next, after assembling the tools, create a coding program to connect the tools, sensors and applications that have been designed.

c) Checking whether the sensor can work as desired, if the sensor does not appear in the application it means repairs must be made.

d) Before carrying out repairs, first pay attention to the tools such as the cooling fan and water pump, if they work then there is an error in the application because the application does not show sensor results, if some of the tools do not work then there is an error in programming the connectivity part between the tool and the sensor.

e) When the sensor does not work, there must be an improvement in the program coding between the sensor and the ESP8266.

f) Next, after all the sensors are working and the application displays the sensor results, you can then pay attention to the results of several captured sensors.

g) For the soil moisture sensor, if the soil moisture has returned to normal results, there is nothing that needs to be repaired. If the sensor reads that the humidity has decreased below 60%, the sensor will give a command to the water pump in the bucket that has been filled with fertilizer mixture which will then be poured onto the tomato plants. cherry.

h) The temperature sensor uses DHT11 which will read the temperature inside the greenhouse, where when the temperature is normal there is no action from the cooling fan, but if the temperature rises above 24˚C then the cooling fan will run.

i) The next sensor is the pH-4502c sensor which will read the bucket for watering. This sensor will read the increase or decrease in pH in the bucket. If the sensor reads the pH increases, the water pump in the bucket containing water will fill the watering bucket and vice versa.

j) After everything is working and connected, the results of several tests will be taken from several tools, sensors and application displays, all will be connected and finished, if not then go back to check one by one.

The display design in the application is made into four display pages, namely Home, Temperature Data, pH Data, and Humidity Data.

The first display is a Home display which displays the main menu of this application, namely a picture of a green house, the words Home Page, the name of the application and several menu icons in the application. The second screen is a display of the greenhouse temperature, more precisely the temperature in the room, the data of which is displayed in real time and will provide information if the fan is working if the sensor reads a temperature increase above 26°C. On the third screen there is a display of the pH of the watering water showing real time data from the pH sensor in the blue bucket in the greenhouse design image according to performance. On this screen, soil moisture data will appear on the cherry tomato planting medium, then for appearance here there are two plants which are the main objects on the display, namely plant one and plant two, the sensor will read the percentage of dryness of the planting medium which will later will be displayed in the application. To store sensor value data requires a real-time database, and in this research, Firebase is used. For the settings, the Firebase section uses Realtime Database menu.

3. RESULTS AND DISCUSSION

The hardware used is ESP8266, 8 channel relay, Soil capacitive moisture sensor v2.0, DHT11, DC pump, 12v portable fan, pH-4502c sensor. This tool was created to make it easier to monitor plants in the greenhouse. The series of hardware devices is presented in Figure 5.

Figure 5 Hardware System

Then, the greenhouse that has been built is shown in Figure 6, which contains two cherry tomato plants.

Figure 6 Greenhouse Smart Farming Prototype

Temperature measurement testing using the DHT11 sensor and thermometer, and comparing the results of temperature data readings on each tool. Table 1 shows the results of temperature measurements via the DHT11 sensor and Thermometer.

Table 1. Temperature Measurement Results

Time	DHT11	Thermometer	Success Percentage
09.30	29.21 °C	29.10 °C	100%
11.30	31.40 °C	31.24 °C	100%
13.30	32.24 °C	32.20 °C	100%
15.30	30.60 °C	30.37 °C	90%

Table 2 shows the results of humidity measurements using the Capacitive soil moisture humidity sensor, according to the depth of the sensor implantation and the sensitivity of the sensor.

Table 2. Humidity Measurement Results

Sensor	Time	2 cm of Depth	4cm of Depth	7cm of Depth
Capacitive soil Moisture	09.30	33%	72%	93%
	11.30	28%	69%	102%
	13.30	31%	76%	104%
	15.30	31%	76%	104%

This sensor test measures the accuracy of the pH-4502c sensor according to the influence of water and AB mix fertilizer specifically for tomatoes. The size of fertilizer A is 250ml and fertilizer B is 250ml and what is needed for 1 liter of water is around 5 ml. The following is a table of testing the pH-4502c sensor which can be seen in Table 3.

Table 3. pH Measurement Results

Sensor	Water	AB mix	pH
pH-4502c	1 Liter	5 ml	6.9
pH-4502c	1 Liter	6 ml	6.6
pH-4502c	1 Liter	5 ml	6.7
pH-4502c	1 Liter	6 ml	6.5

Application implementation is the application of source code to an application on a smartphone. The appearance of the microcontroller greenhouse application on Android will display the display in automatic mode, starting from displaying the temperature and humidity of the air, displaying the soil moisture in the two plants and the pH of the water for watering the plants as a means of monitoring and knowing what is happening in the greenhouse according to the criteria. monitoring, in the monitoring data log as monitoring all activities that run every two hours. The application display can be seen in Figure 7 and Figure 8.

Figure 7 Home Display on Android

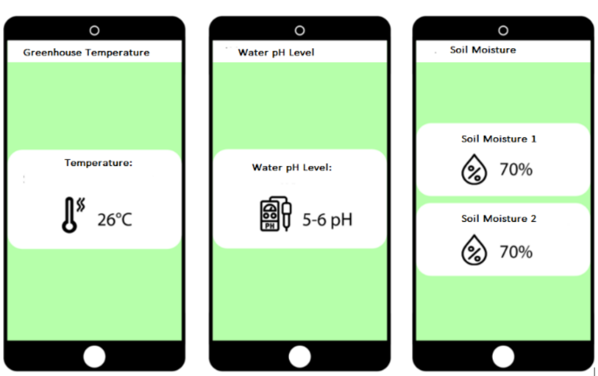

Figure 8 Display of Temperature, pH and Humidity

The display of the monitoring system application on Android can be seen in the image above, which has successfully displayed home screen data, temperature, pH value and humidity online and in real-time.

4. CONCLUSION

The automation in the smart farming system works automatically according to the program written on the esp8266 between tools and sensors. In the Android-based monitoring system application section, there is a home screen page, menu page, temperature page, pH value, humidity, and Monitoring Log page, each of which displays data read from the sensor, then sent to Firebase and then the data from Firebase is displayed in the application. which was previously created in MIT App Inventor. This system has several advantages, including that it can be run using an Android smartphone, monitors plants in the greenhouse, can be controlled remotely, and makes it easier for users to control watering. This system still has shortcomings, so it can be an opportunity for further development research, namely by adding many features to Android applications, making Android applications with a more modern user interface, using the paid Firebase database, not free so there are no limits, and adding several sensors. such as light intensity, other water systems, etc.

AUTHORS' CONTRIBUTIONS

Principal Investigator (Marti Widya Sari): Coordinating research with the research team and partners, mapping hardware and software system requirements, compiling publication articles.

Research Member 1 (R. Hafid Hardyanto): Coordinating with user partners, and preparing agricultural land for system trials.

Research Member 2 (Prahenusa Wahyu Ciptadi): Simulated the system before testing it in the field, and evaluated the results of system testing.

Research Member 3 (Eni Kriswandari from BAPPEDA Bantul): Mapping the potential for developing the Smart Farming model.

Student (Bayu Linggar Pangestu): tasked with assisting with surveys, data processing, preparing FGDs, and documenting research activities.

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