Smart Greenhouse Design Based Internet of Things (IoT) With Microcontroller Arduino Uno

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ABSTRACT

Technological developments are increasingly rapid. However, it has not spread evenly among the people. Most people still use traditional methods and depend on the uncertain climate to meet their food needs, such as vegetables and fruits. Based on this, an Internet of Things (IoT) based Smart Greenhouse Design with Arduino Uno Microcontroller was created as a solution that is expected to help make it easier for farmers to cultivate plants. The greenhouse is a building that has the function to protect plants from external disturbances such as pests, heavy rain, strong winds, and excessive humidity. Meanwhile, what is called a smart greenhouse that uses technology such as the Internet of Things (IoT), is designed to automatically monitoring uses the Arduino Uno microcontroller as the control center for each sensor used, namely DHT22 (air temperature and humidity sensor), Soil Moisture (soil moisture sensor), GUVA-S12SD (UV light intensity sensor). The sensor will obtain the required data and will be automatically sent to the server (blynk application) with the help of ESP8266 (wifi module). The method used in this study is engineering design in the manufacture of the automation system. The results of this research are in the form of a smart greenhouse that can regulate, adjust, and modify the climate to optimize the conditions and processes of plant growth in the greenhouse equipment through microcontrollers and monitoring devices such as sensors and can be controlled remotely via mobile phones or computers everywhere.

Keywords: design, smart greenhouse, internet of things (IoT), engineering design.
1. INTRODUCTION

The rapid and sophisticated development of today's technology certainly plays a major role in almost every aspect of human life in helping to solve various problems, especially in the agricultural sector [1]. In the modern era of the 4.0 revolution, many advanced technologies have been applied in world agriculture [2]. As seen in large countries, namely the United States, Australia, Japan, Korea, China, the Netherlands, and other countries with sophisticated agricultural technology, one example of its application is to cultivate plants in a modern way using greenhouse technology.

Innovations in agriculture continue to develop and have entered Indonesian territory, especially in big cities where sophisticated technology has been applied to support agricultural production, including the greenhouse technology itself, where greenhouses are used to cultivate horticultural crops such as fruits and vegetables [3].

Greenhouse technology is of course very helpful for agricultural systems in developing countries like Indonesia because climate change that has occurred in recent years has become a major concern, especially in developing countries that have had a major impact on the agricultural sector such as crop failure due to drought. Given the important role of the agricultural sector in the development of developing countries and its status as the backbone of the economy, meeting people's daily needs, alleviating poverty, and creating jobs, the application of greenhouse technology can be an opportunity to overcome the problems that occur [4].

However, the development of this technology has not spread evenly among the public, especially in remote areas. Most people today still use traditional methods and depend on an erratic climate to meet their food needs such as vegetables and fruits [5]. Farmers in remote areas are also faced with challenges when adopting modern technology such as smart greenhouses, this is due to a lack of knowledge and adequate access to information regarding this technology and limited costs [6].

There is a solution to overcome this problem along with innovation in agriculture, namely by utilizing smart greenhouse technology, usually referred to as a smart farming system or smart farming [7]. However, so far the monitoring and control of the greenhouse system still use manual methods, such as how maintaining moisture in the plants by manually watering and measuring temperature using a thermometer for environmental conditioning [8].

Therefore, utilizing smart greenhouse technology is expected to make it easier for farmers to cultivate crops. The smart greenhouse concept is to regulate, adjust, and modify the climate to optimize the conditions and growth processes of plants in the greenhouse through microcontroller equipment and monitoring devices such as sensors which can be controlled remotely [9]. A system that can be controlled automatically and is not limited by distance with the Internet of Things (IoT) where every device is connected to the Internet so that it can be controlled directly from anywhere and anytime [10].

To support the application of smart greenhouse technology, a participatory approach is needed and involves farmers in the development process and provides better accessibility to technology through outreach and training as well as financial support such as government assistance or business-based financing that can help farmers overcome existing obstacles.

Previously there had been related research that discussed the technology of smart greenhouses.

Previous research designed a greenhouse monitoring system that is expected to increase efficiency in farming and maintain environmental factors that affect plant growth using the prototype method. The research aims to determine plant growth and fertility to get maximum results by using automatic watering technology which is integrated with applications so that it can be accessed in real-time real-timing plant growth based on the data obtained. However, the designed system can only monitor greenhouse conditions and cannot control the system yet [11].

Subsequent research designed a device to automatically control temperature, humidity, and light intensity in a greenhouse for shallot plants using the prototype method. The designed tools can run according to their respective functions and according to planning, but the sensors used are still limited and incomplete[12].
Furthermore, there is research that aims to create tools for monitoring and controlling the microclimate conditions in greenhouses with an IoT platform, namely the Blynk application. Based on the research results, a prototype system and tool can be built and designed to monitor and control the greenhouse microclimate [13].

Designing a prototype of an automatic control system for greenhouses based on Arduino and IoT for chili plants. The circuit works so well that the automated system for chili plants is based. However, details of the greenhouse design are not displayed and no tool kit combines all the components as a whole [14].

There is research that aims to design and create a system to facilitate the cultivation of hydroponic plants using smart greenhouse technology that can be run automatically using Arduino Uno as a microcontroller. Using the prototype method, but he did not explain whether the sensor test was by the system design built for the process of cultivating plants in a greenhouse [15].

Based on the description of the background above, the author raised the title of this study namely "Smart Greenhouse Design Based Internet of Things (IoT) with Microcontroller Arduino Uno."

2. METHODS

In developing this smart greenhouse design, the engineering design method is used to make the automation system. The design engineering method is a series of activities that cover the design, development, and implementation processes which in practice lead to new changes in the form of processes or products, this method will produce automation tools that are structured and focus on each stage of the process [16].

The stages of the research include the steps for carrying out the research to be taken starting from the beginning to the end as described in Figure 1.

2.1. Identification of problems

In the first stage, namely problem identification, researchers identify problems encountered in the field such as unstable weather factors affecting the fulfillment of food needs such as vegetables and fruits so breakthroughs are needed in agricultural systems by utilizing smart greenhouse technology.

2.2. Analysis of Functional and Non-Functional Needs

This stage is to identify the needs before designing the tool. In designing a smart greenhouse, the functional and functional requirements in this study include electronic and mechanical components. In addition, the concept of the Internet of Things (IoT) is very important in tool design. The components needed are an Arduino Uno which functions to control the temperature and humidity sensor (DHT22) and an ultraviolet intensity sensor (GUVA-S12SD) which functions to acquire data on microclimate conditions in the greenhouse, as well as a soil moisture sensor (Capacitive Soil Moisture).

2.3. System Design and Testing

System design and testing are the stages for designing an Internet of Things (IoT)-based smart greenhouse controlled by a microcontroller. The beginning of this stage is to carry out the overall system planning process.
by preparing the tools and materials needed. After that proceed to the system design process where the design process is divided into two parts, namely the mechanism design and system design.

2.3.1 System Design
The system design process aims to provide an overview of the smart greenhouse design that will be developed. The system design includes mechanical design for the greenhouse frame using Sketchup software, hardware design using Fritzing software, and smart greenhouse code design using Arduino IDE software.

2.3.2 Mechanism Design
Mechanism design aims to develop the flow and workings of the system to be designed. The mechanism design includes the design of a block diagram along with how the smart greenhouse system works which is explained using a flowchart.

2.3.3 Testing
System testing is needed to find out how the designed system works well according to expectations based on certain parameters. In this study, several tests were carried out, namely as follows:

a. Testing of monitoring and controlling devices
   The testing process is carried out on each device which aims to find out whether the Arduino Uno microcontroller is integrated with sensors and can carry out monitoring and automation processes properly. Tests are carried out by monitoring the greenhouse according to the function of each device whether the device can work according to its function such as reading the values of temperature, humidity, soil moisture, and UV, radiation intensity.

b. Testing the sending data from sensor monitoring results
   This test aims to determine the completeness of the data sent to the server. The testing process was carried out with monitoring and automation experiments on Arduino Uno with the help of ESP8266 sending sensor monitoring results in data via wireless to the server.

3. RESULTS AND DISCUSSION

This section describes the design of the tool which consists of mechanical design, electronic circuit design (hardware), and software design, as well as how the smart greenhouse system works, data display on the server, and the result of the test.

3.1 Research result
3.1.1 Tool Design
Tool design consists of three main parts, namely: mechanical design, electronic design (hardware), and software design (software).

3.1.2 Mechanical design
The mechanical design process uses Sketchup software to design the greenhouse frame. The greenhouse framework needed is as follows:

1. Ingredients
   a. Iron for greenhouse framework (zinc battens, channel c, foll ceiling)
   b. Bout rilling
   c. UV plastic for walls and roofs
   d. Glue

2. Size
   a. Length: 5 meters
   b. Width: 3 meters
   c. Height: 2.50 meters

3. Greenhouse model: gable

The greenhouse frame design can be seen in Figure 2

![Figure 2. Design of a greenhouse frame](image)

3.1.3 Hardware Design
Hardware design begins with making block diagrams followed by electronic circuit design using fritzing. The block diagram for designing a smart greenhouse based on the Internet of Things (IoT) with the Arduino Uno microcontroller is shown in Figure 3.
The following is an explanation of the block diagram in Figure 3.

a. Voltage Source Block (Power Supply)

The power supply block functions to supply voltage to each block, namely the input block, process block, and output block [22].

b. Input Block

In the design of the input block as shown in Figure 3 several sensors and components will work according to their respective functions. The following are the components contained in the input block.

1. Temperature and humidity sensor (DHT22)

This sensor functions to measure and detect the humidity and temperature of the air in the greenhouse [17].

2. Soil moisture sensor

Soil moisture sensors are used to measure water content and soil moisture in plants [18].

3. Ultraviolet light intensity sensor (GUVA-S12SD)

GUVA-S12SD sensor as an ultraviolet light detector in a greenhouse [19].

c. Process Block

There are two types of microcontrollers in the process block design namely.

1. Arduino Uno

Arduino Uno functions to read sensor data and then send the data to the server via the internet with the help of the ESP8266 [20].

2. ESP8266

The wifi module (ESP8266) is an Arduino enhancement to connect to the internet network (wifi) [21].

d. Output Block

In Figure 3 there is an output block design in the form of results obtained from the process block, namely the server. The server functions to store and accommodate sensor data sent by Arduino Uno with the help of the ESP8266 module which will later be displayed on the Blynk application so that it can be used by users to monitor and control greenhouse systems. The following is an electronic circuit design using fritzing.

![Figure 3. Block Diagram](image)

![Figure 4. Electronic circuit design (hardware)](image)
Table 1 Description of electronic circuit pins (hardware)

<table>
<thead>
<tr>
<th>Cable Color</th>
<th>Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>VCC (Voltage)</td>
</tr>
<tr>
<td>Yellow and green</td>
<td>Data</td>
</tr>
<tr>
<td>Black</td>
<td>Ground (Negative Pole)</td>
</tr>
<tr>
<td>Brown</td>
<td>TX</td>
</tr>
<tr>
<td>Purple</td>
<td>RX</td>
</tr>
<tr>
<td>Blue</td>
<td>SDA</td>
</tr>
<tr>
<td>Orange</td>
<td>SCL</td>
</tr>
</tbody>
</table>

Table 2 Description of components and circuit pins

<table>
<thead>
<tr>
<th>Sensors/Components</th>
<th>Arduino pins</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHT22</td>
<td>VCC, GND, D7(Arduino)</td>
</tr>
<tr>
<td>GUVA-S12SD</td>
<td>VCC, GND, A0(Arduino)</td>
</tr>
<tr>
<td>Soil Moisture</td>
<td>VCC, GND, A1(Arduino)</td>
</tr>
<tr>
<td>Relay</td>
<td>VCC, GND, D8 (Arduino)</td>
</tr>
<tr>
<td>ESP8266</td>
<td>VCC, GND, TX, RX</td>
</tr>
<tr>
<td>LCD</td>
<td>VCC, GND, SDA, SCL</td>
</tr>
</tbody>
</table>

The design of electronic circuits is designed using fritzing software. Figure 4 is a schematic combination of each hardware component as a whole. In Figure 4 Arduino Uno is the main component in controlling and controlling sensors. ESP8266 receives input from Arduino and processes the data and then sends it to the server (blynk) using wireless media.

A more detailed explanation can be seen in Figure 5.

Figure 5. Smart greenhouse control components

Based on Figure 5, it can be seen how the components in the greenhouse work together, there is an Arduino Uno as the control center for sensors namely DHT22 which functions to detect temperature and humidity in the greenhouse room, then soil moisture sensors which are in charge of detecting soil moisture in plants and sensors GUVA-S12SD to measure the index and intensity of ultraviolet light intensity in a greenhouse. Then the relay is an electronic switch whose job is to control the water pump automatically to turn on the misting cooling system. The misting cooling system functions to help lower the air temperature. This is because when water vapor in the form of fog evaporates, the air will become cooler. The water pump will work and take water from the reservoir and flow it through the hose that has been connected and installed with a spray nozzle. The high-pressure water pump allows water to come out of the spray nozzle in the form of small-diameter droplets like mist. This helps the cooling process and keeps the indoor temperature of the greenhouse at a lower level. All sensors and components such as relays and ESP8266 as additional devices that help Arduino in sending data via wireless to the server (blynk) are connected to Arduino Uno. When the DHT22, soil moisture, and GUVA-S12SD sensors are turned on, data such as temperature and humidity, soil moisture, and UV light intensity will be sent to the server (blynk) to be monitored and taken control measures such as turning on a misting cooling system to help control temperature in greenhouses.
3.1.4. Software Design

The software design process is focused on Arduino programming using the Arduino IDE (Integrated Development Environment) software to create smart greenhouse program code. The display of the smart greenhouse program code using the Arduino IDE software is shown in Figure 6.

**Figure 6. The smart greenhouse program code**

3.1.5. How the Internet of Things (IoT) Based Smart Greenhouse System Works

- **Start**
- **Initialization**
- **Read Soil Moisture Sensor data, DHT22 & GUVA-S12SD**
- **Arduino processes data**
- **ESP8266 Send data to server (Blynk)**
- **Check Internet Connected**
  - **Yes**
    - **Servers receive data**
    - **Display Soil Moisture Sensor data: DHT22 & GUVA-S12SD**
    - **If soil moisture <500**
      - **Relay ON**
      - **Relay Standby Water pump ON**
    - **If soil moisture >500**
      - **Relay OFF**
  - **No**
    - **End**

Figure 7 shows how the Internet of Things (IoT) based smart greenhouse system works. The process begins with the initialization of electronic equipment and continues with the reading and processing of soil moisture sensor data, temperature and humidity sensors (DHT22), and ultraviolet light intensity sensors (GUVA-S12SD) by the Arduino Uno microcontroller. Then proceed with the sensor data distribution process using the help of the wifi module (ESP8266) to the server (blynk) after the sensor data reading process is complete, followed by checking the condition of the internet connection, if connected, the server will receive data from sensor readings carried out by the microcontroller. However, if it is not connected, the sensor data distribution process will repeat itself. Then the process will continue when the soil moisture sensor results show a number that exceeds a predetermined threshold. If the soil moisture is <500, the microcontroller will instruct the relay to turn on the water pump. However, if the soil moisture is >500, the microcontroller will instruct the relay to stop, otherwise, the humidification process will continue until the soil moisture reaches normal values.

3.2. Test result

Overall the system testing process is carried out by combining all electronic components, hardware, and software as well as the process of checking air temperature and humidity, ultraviolet light intensity, y, and soil moisture on plants in the greenhouse then the process of sending, receiving, and displaying data on the server (blynk).

a. Testing of monitoring and controlling devices

The results of monitoring and controlling device testing are shown in Table 3 and Table 4.
Table 3. The process of designing and testing monitoring and controlling devices

<table>
<thead>
<tr>
<th>Design</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Image of design process]</td>
<td>[Image of test process]</td>
</tr>
</tbody>
</table>

The testing process is carried out to find out whether each component in the smart greenhouse series can work properly as expected, as shown in Table 4.

Table 4. Test results for monitoring and controlling devices

<table>
<thead>
<tr>
<th>No</th>
<th>Device Name</th>
<th>Testing</th>
<th>Status</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arduino Uno microcontroller</td>
<td>Program uploads</td>
<td>✓ -</td>
<td>On</td>
</tr>
<tr>
<td>2</td>
<td>ESP8266</td>
<td>Send data to the server</td>
<td>✓ -</td>
<td>On</td>
</tr>
<tr>
<td>3</td>
<td>Soil Moisture sensor</td>
<td>Take the soil moisture value</td>
<td>✓ -</td>
<td>On</td>
</tr>
<tr>
<td>4</td>
<td>DHT22 sensor</td>
<td>Take the temperature &amp; humidity values</td>
<td>✓ -</td>
<td>On</td>
</tr>
<tr>
<td>5</td>
<td>GUVA-S12SD sensor</td>
<td>Take the intensity value of the ultraviolet light</td>
<td>✓ -</td>
<td>On</td>
</tr>
</tbody>
</table>

Table 4 continued...

<table>
<thead>
<tr>
<th>No</th>
<th>Device Name</th>
<th>Testing</th>
<th>Status</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>LCD 16x2</td>
<td>Display Information</td>
<td>✓ -</td>
<td>On</td>
</tr>
<tr>
<td>7</td>
<td>Relay</td>
<td>Switch On/Off</td>
<td>✓ -</td>
<td>On</td>
</tr>
<tr>
<td>8</td>
<td>Water Pump</td>
<td>Relay On water pump On</td>
<td>✓ -</td>
<td>On</td>
</tr>
</tbody>
</table>

Based on the results of monitoring and controlling device testing, it was found that each component can work and function properly.

a. Testing the delivery of data from sensor monitoring results

The test results are generated by the sensor by using an automatic water pump for the misting cooling system. The results of data collection for DHT22, soil moisture, and GUVA-S12SD sensors for one day starting from 10.00 WITA to 00.00 WITA is shown in Table 5.

Table 5. Data from sensor monitoring results

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Temperature</th>
<th>Air humidity</th>
<th>UV intensity</th>
<th>Soil moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>31/08/2022</td>
<td>10.00</td>
<td>33º</td>
<td>87%</td>
<td>134</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>11.00</td>
<td>33º</td>
<td>98%</td>
<td>116</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>12.00</td>
<td>35º</td>
<td>65%</td>
<td>103</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>13.00</td>
<td>42º</td>
<td>70%</td>
<td>90</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>14.00</td>
<td>42º</td>
<td>59%</td>
<td>92</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>15.00</td>
<td>38º</td>
<td>62%</td>
<td>59</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>16.00</td>
<td>38º</td>
<td>59%</td>
<td>93</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>17.00</td>
<td>29º</td>
<td>93%</td>
<td>55</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>18.00</td>
<td>26º</td>
<td>99%</td>
<td>40</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>19.00</td>
<td>26º</td>
<td>99%</td>
<td>40</td>
<td>255</td>
</tr>
</tbody>
</table>
Table 5 continued...

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Temperature</th>
<th>Air humidity</th>
<th>UV intensity</th>
<th>Soil moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>31/08/2022</td>
<td>20.00</td>
<td>25º</td>
<td>99%</td>
<td>39</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>21.00</td>
<td>24º</td>
<td>99%</td>
<td>39</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>22.00</td>
<td>24º</td>
<td>99%</td>
<td>40</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>23.00</td>
<td>24º</td>
<td>99%</td>
<td>40</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>00.00</td>
<td>23º</td>
<td>99%</td>
<td>39</td>
<td>255</td>
</tr>
</tbody>
</table>

Table 5 is the result of data collection on the greenhouse in one day, the process of monitoring air temperature and humidity with the DHT22 sensor, ultraviolet light intensity using the GUVA-S12SD sensor, and soil moisture using the capacitive soil moisture sensor which is done every hour.

Based on the readings, the temperature and humidity sensors, and the intensity of the ultraviolet light sensor, have increased from morning to noon and began to decrease in the afternoon to evening. While the soil moisture data remained the same after watering.

The display of data on the server can be seen in Figure 8.

![Figure 8. Server view (blinky)](image)

CONCLUSION

After conducting the research process, it can be concluded that the smart greenhouse design using the Internet of Things (IoT) concept can automatically run well. The designed program can also work as expected, such as sending data to the server, displaying temperature and humidity data, ultraviolet light intensity and soil moisture in real-time, and temperature conditions in the greenhouse using a misting cooling system. Using the ESP8266 can help Arduino Uno send monitoring data to the server to make it easier to control greenhouse conditions from anywhere and at any time as long as it is connected to an internet network.

Based on the results of this study, several suggestions can be used to develop further research, namely as follows.

1. Ventilation can be added to the greenhouse building to facilitate air circulation inside.
2. Adding a water filter so that the misting cooling system can run smoothly and is not clogged.
3. Ensure that the internet connection used is good so that it can support sending sensor data to the server.
4. Adding a water level sensor to monitor the water level in the tank if it runs out.

REFERENCE

Lakeisha, 2019.


