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Application of Internet of Things in Smart Greenhouse Microclimate Management for Tomato Growth

Nurpilihan Bafdal[a,*], Irfan Ardiansah[b]

[a] *Department of Agriculture Engineering and Biosystem, Faculty of Agro-Industrial Technology, Universitas Padjadjaran, Bandung, Indonesia*

[b] *Department of Agro-Industrial Technology, Faculty of Agro-Industrial Technology, Universitas Padjadjaran, Bandung, Indonesia*

*Corresponding author: *nurpilihanbafdal@yahoo.com*

***Abstract*— Microclimate control is very important for the cultivation of plants in greenhouses. Some microclimate variables are temperature and humidity, these variables can be controlled using several methods, one of which is the misting of the cooling system, but this process is still done manually. This research aims to create an internet-of-things-based system to automatically control the greenhouse microclimate, controlled and controlled through a website. The results showed that the system could automatically activate the cooling system misting when the temperature is above 30 °C and the humidity is below 80%. The greenhouse microclimate data can be controlled and controlled via the website. The automation system works better in maintaining the greenhouse's microclimate conditions than before using the automation system with a difference of 6.25 ˚C temperature and 28.06% higher humidity. Microclimate data can be displayed and accessed via the website, and minimum and maximum temperatures can be set via the website. The factor that affects the greenhouse temperature is the UV index. The higher the UV index, the higher the temperature. When the UV index reaches < 10, the greenhouse temperature can still be reduced to ± 3 °C. If the UV index > 10, the temperature can still be reduced to a smaller value. The automation system's microclimate data processing is more effective, accurate, and the performance of the automation system reaches 115.22% but will decrease to 80.40% when the light intensity is high.**

***Keywords*— internet of things; greenhouse; microclimate; misting cooling system; raspberry pi**

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I. INTRODUCTION

The climate in the world is getting warmer for various human activities and increasing levels of CO2 which results in the greenhouse's emergence effect. Greenhouse gases are an important factor in instability during the changing seasons because of excessive energy use. Various levels of microclimate influence various plants in a smart greenhouse. To protect plants, the microclimate must be arranged in such a way as to be suitable and optimal for plant growth [1], [2].

Therefore, environmental conditions inside the smart greenhouse should be protecting the crop from microclimate like temperature, humidity; pH; solar radiation; soil media, and pests and diseases [3]. The principal purpose of protected plant growth in a smart greenhouse is to create an optimum potential environment for various plants, even in adverse microclimate conditions. There are two major favorable microclimates in a smart greenhouse. These are temperature and humidity for the sustained growth of the tomato plant, which ultimately provides quantity and quality of tomato growth [4]. Microclimate modification is to realized optimum in the smart greenhouse to improve the tomato yield. Some farmers, until this time they control microclimate, are still done manually in the smart greenhouse, but it is unfortunate that conditions still cannot be monitored and changed property so the plant yield still cannot be maximized [5], [6]. Smart greenhouse management should service protect plants from excessive micro-climate such as heat and cold; temperature, humidity, pH, and all parameters will proceed automatically by information technology. One alternative is the Internet of Thing using the mist cooling system [7], [8]. The development of modern information technology is expected to help overcome some problems on microclimate conditions in the smart greenhouse and be easier to maintain in control [9].

Application of the Internet of Things (IoT) in a smart greenhouse using a mist cooling system expected could change extreme temperature and humidity to the optimum potential for tomato growth; it is to solve problems found in plant growth, especially found in tomato hydroponic cultivation [10]. Protected plant growth is usually favorable to sustainable microclimate and realizes its maximum production even than the need for various environmental conditions [11].

A. Internet of Things

The Internet of Things (IoT) is one of the key elements in the development of this revolution. The existence of the IoT is very useful in various fields of life, particularly in agriculture. The utilization of IoT in agriculture can smart greenhouse technology. The application of IoT in the greenhouse system can monitor microclimate such as temperature, humidity, and in real-time, the farmers can control the plant remote [12].

Internet of Thing is a platform which used cable and wireless sensor for data process by sensory until becoming information, and daily communication becomes precision. The Internet of Things concept is divided into three layers. These are sensing, data transfer, and application (data safety [13]. IoT technology will be alternative methods that are very popular for various agriculture plants such as tomatoes. IoT in the agriculture sector was expected to raise productivity and predict future harvesting and solve some problems in the agricultural system. The Internet of Things in agriculture also very potential because the farmers could raise food and animal operational production [14].

Various are suitable to get an available monitoring environment in a smart greenhouse such as a microclimate which as temperature and humidity can be controlled using several methods, but the mist cooling is one option to sensors and controllers can change it for tomato growth. Data in a smart greenhouse will send it to the control station over the internet. Tomato is one of the most popular horticulture plants in Indonesia, because high vitamin C (25,16 mg/100 gram); protein (2,18%), fat (0,26%), and carbohydrate (6,01%); but tomato required a relatively cold climatic environment were needed temperature between 18 ºC to 28 ºC and humidity between 80% to 90% to get high yield and excellent quality [15].

Using the mist cooling system on microclimate with high precision; could help tomato farmers predict harvest data and control, monitoring automatically in the smart greenhouse, such as high temperature and low humidity during a dry season [16]. Application of the Internet of Thing was a big data analysis for automatically condition process to make pleasant activities with actual time and usually influenced in the agriculture sector by technology [8]. The realization of IoT makes farmers work more easily, effectively, and efficiently because farmers do not need to control the engine, but the engine will control themselves and collaborate with other engines.

B. Smart Greenhouse

A smart greenhouse or precision greenhouse or intelligent greenhouse builds and protects plants' growth from excessive heat, cold, dust, and control from pests and diseases. A smart greenhouse automation system is the technical approach in which automatic monitoring and control of a smart greenhouse environment will benefit the farmers. A smart greenhouse is made as monitoring automatically of monitoring and controlling microclimate used the sensors and farmers need not control and to spend on expensive monitoring and problems, cost-effective than get optimum temperature, for varied plant growth remotely. Urbanization will affect the lack of land availability: there is a need to build a smart greenhouse used mostly for growing crops like a tomato [17]–[19].

The utilization of methods in the smart greenhouse uses not only information technology but also the main key. Therefore, the method system measured the parameters needed by plants, especially tomatoes, such as maintenance for tomato plants, which will be more controlled compared to a tomato grown outside a smart greenhouse. Figure 1 below shows the smart greenhouse in Indonesia.

Fig. 1 Tomato Plants inside Nudira Fresh Greenhouse

II. Material and Methods

The research was conducted from January to March 2020 in a smart greenhouse on Universitas Padjadjaran Jatinangor, Sumedang West Java province of Indonesia. The research aims to design the application technology of the Internet of Things using mist cooling on microclimate, which is temperature and humidity in a smart greenhouse for tomato growth, as shown in Figure 2. The data required in the smart greenhouse for tomato growth is estimated temperature between 20 ºC to 28 ºC; while humidity between 80% to 90% in all seasons. The sensor data will be accessed from anywhere from the internet or smartphone and updated every 20 minutes.

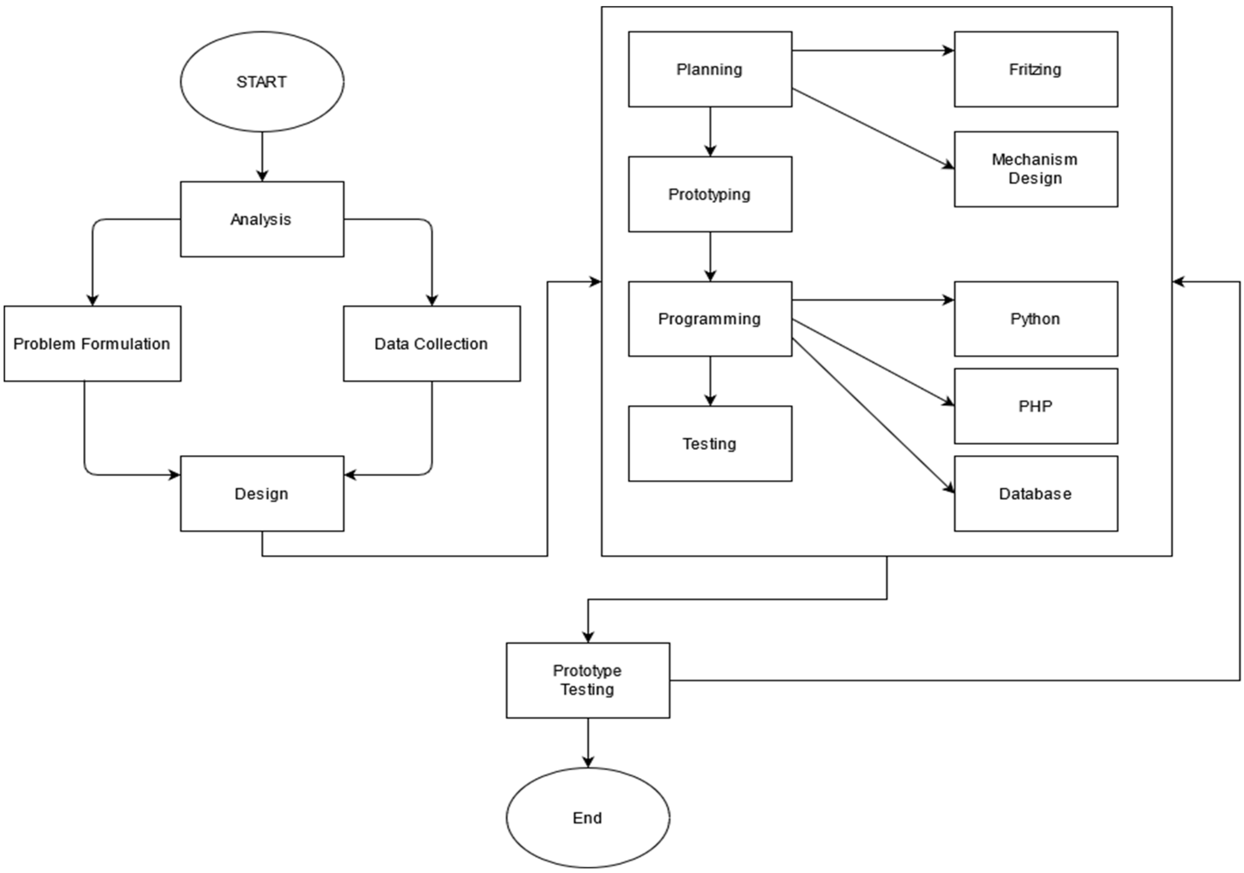


Fig. 2 Research Stages Flowchart

A. Instruments

The hardware used in this research are:

- Raspberry Pi 3 Microcomputer Version B,
- SHT11 sensor, a digital type of sensor for measuring air temperature and relative humidity,
- GUVA-S12D, an analog type of sensor used for the index of sunlight intensity,
- The fogging system with an emitter can spray 3 microns of water,
- Low-pressure water pump to push air so it can form fog,
- Relays, electronic components that provide voltage lines using low-voltage signals.

The software used in this research are:

- Raspberry Pi OS, the operating system used to operate the Raspberry Pi
- Python 3, a scripting programming language used to control hardware, retrieve data from sensors and manage the database.
- PHP, a web programming language used to display all information in the database.
- MariaDB, a database application for storing data acquired by Python 3.
- Putty, a text-based remote application that is used to access Raspberry Pi OS using Windows OS.
- WinSCP, a Windows OS-based remote application that is used to transfer files to Raspberry Pi OS.

B. Research Methodology

The research was carried out in the ALG Unpad Greenhouse in Pedca Utara Universitas Padjadjaran with coordinates of 6 ° 55'13.9 "S 107 ° 46'27.5" E. The research was conducted using the design method for 3 months, and then the device was tested in a greenhouse for 25 days by acquiring sensor data every minute. The data stored in the database is then analyzed using statistical analysis. It automatically converts the data stored in the database into Comma-Separated Values (CSV) format so that the data will be easier to process using a spreadsheet application.

C. Research Procedure

The automation devices that have been built are then integrated into the ALG Greenhouse as shown in Figure 3 below:

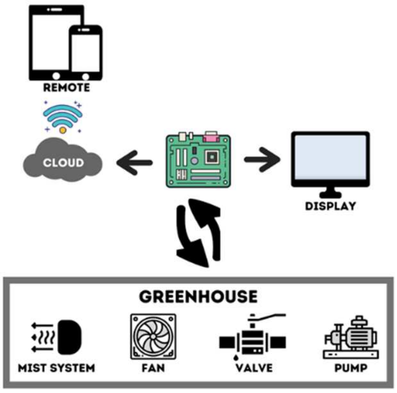


Fig. 3 Diagram of Smart Greenhouse Automation System

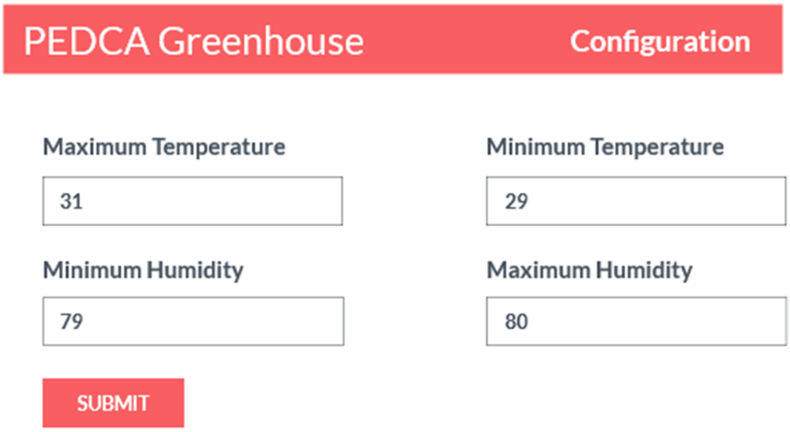
The fogging system pipe is made in the form of a trident with 18 (eighteen) fog valve points so that the mist distribution can reach all points in the greenhouse when conditions are not ideal. The device runs from 06.00 - 18.00 every day. All sensor data is immediately recorded every minute into the database.

The data is then processed and displayed in tabular form on a website that can be accessed via the internet using DynDNS's services, as seen in Figure 4a. Temperature and relative humidity configuration parameters are set through the admin page seen in Figure 4b, which is directly updated after the greenhouse administrator clicks on the submit button.

Greenhouse Microclimate

Nu.	Date/Time	Temperature (C)	Humidity (%)	UV Index	Status
1	04-03-2020/10:41:05	35.03	50.59	12	Inactive
2	04-03-202010:41:05	35.03	50.59	12	Active
3	04-03-2020/10:14:30	35.24	50.74	12	Inactive
4	04-03-2020/10:14:30	35.24	50.74	12	Active
5	04=03-2020/09:48:41	33.67	58.59	12	inactive
6	04-03-2020/09:48:41	33.67	58.59	12	Active
7	04-03-2020/09:25:59	32.93	59.72	12	Inactive
8	04-03-2020/09:25:59	32.93	59.72	12	Active
9	04-03-2020/09:08:51	31.54	62.55	12	Inactive
10	04-03-2020/09:08:51	31.54	62.55	12	Active

(a)



(b)

Fig. 4 (a) Micro-Climate Automation System Information Page, and (b) Micro-Climate Automation System Configuration Page

III. Results and Discussion

Greenhouse microclimate data collection with an automation system is carried out every one minute per day. The data was stored in the database and displayed on the website. The data that can be stored in the database can be in the thousands as a reference. The data stored in the database for 25 days is 278,880. If average, the data that can be stored per day reaches ± 11,115, with that much data, it suffices to describe the greenhouse's micro-climate conditions every day accurately, and the data collection is carried out automatically by the system. All microclimate data are then simplified by averaging the data per day so that it only displays the average data for 25 measurement days, as shown in Table 1 and Figure 5, respectively, which shows that there is a close relationship between temperature and humidity with a closeness level of 0.6633 and the formula that can be used to predict the air relative humidity inside Pedca Greenhouse is

$$y = -3.5892x + 173.02 \quad (1)$$

TABLE I
DAILY AVERAGE OF MICROCLIMATE DATA INSIDE SMART GREENHOUSE

Day	Temperature (C)	Humidity (%)
1	25.51	78.31
2	26.77	76.18
3	27.10	72.22
4	26.50	77.54
5	26.06	79.63
6	25.96	78.86
7	25.28	81.76
8	24.02	86.64
9	24.58	83.45
10	24.22	85.22
11	25.64	80.17
12	26.51	77.45
13	26.92	74.86
14	27.06	74.27
15	26.87	76.62
16	26.12	79.18
17	26.09	79.39
18	26.18	79.41
19	26.66	78.97
20	25.45	84.83
21	26.01	84.86
22	25.93	84.57
23	27.08	78.54
24	25.64	77.60
25	25.22	84.26

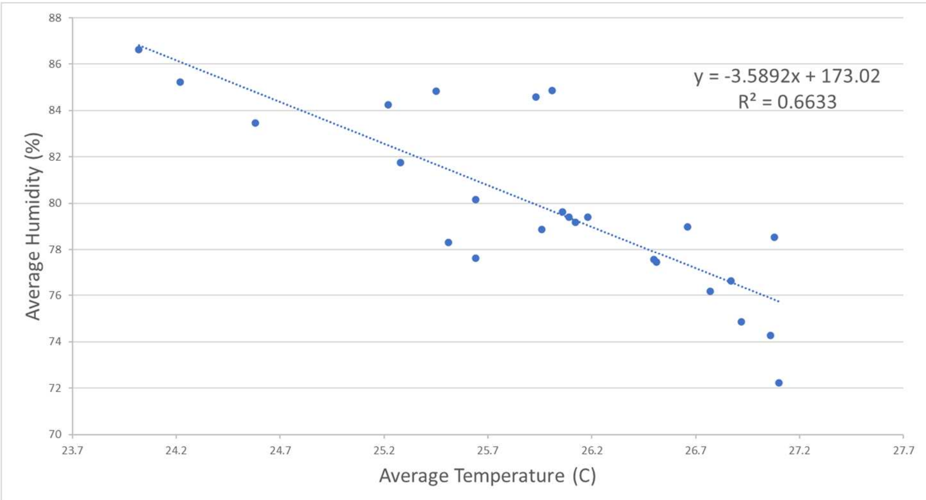


Fig. 5 Scatterplot of Daily Average Microclimate Data Inside Smart Greenhouse

Comparison of micro-climatic conditions carried out on the automation system and the previous system is the average temperature and humidity, maximum temperature, and minimum humidity of the greenhouse microclimate for 25 days at 06.00 - 18.00. The comparison of light intensity cannot be made because the two systems measure two things. In contrast, the automation system measures the solar UV index, while the previous system measures sunlight's intensity.

The data shown in Figure 6 shows that the automation system can work better than the previous system that has not used a cooling system, as evidenced by the difference in average temperature per day, which reaches 6.25 C. Besides using the automation system, it also makes the average temperature the greenhouse temperature per day is below the maximum temperature to maintain in the greenhouse (30 ˚C), which is 25.97 ˚C, 4.03 ˚C less, when compared to the previous system, the average greenhouse temperature per day exceeds the maximum temperature to maintain in the greenhouse (30˚C), which is 32.23˚C, and 2.23˚C. The maximum greenhouse temperature per day generated after using the automation system also has better results than the previous system, as evidenced by the difference in the average maximum temperature per day, which reaches 2.68 ˚C. To calculate the percentage value of the increase in the automation system's performance against the previous system in maintaining the greenhouse temperature, then the value is 19.42% at the average temperature and 6.65% at the maximum temperature.

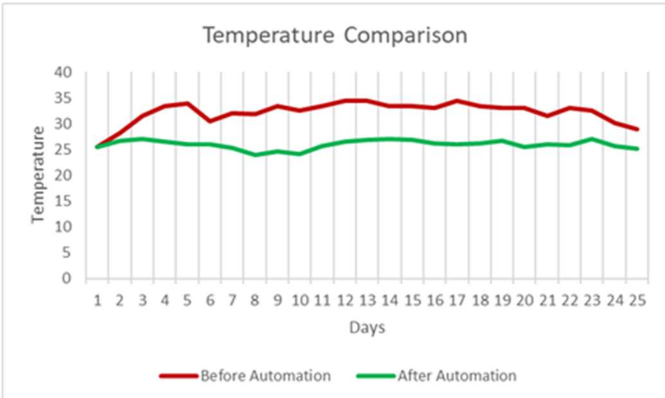


Fig. 6 Comparison between Smart Greenhouse Temperature and Outside Greenhouse Temperature

The data in Figure 7 also shows that the automation system can also work better than the previous system, as evidenced by the difference in average humidity per day, which reaches 28.06%. Besides using an automation system, the average greenhouse humidity is very close to the greenhouse's minimum humidity to maintain in the greenhouse (80%) is 79.79%, only 0.31% smaller. In the previous system, the greenhouse's average humidity per day was very far from the minimum humidity to maintain in the greenhouse (80%), namely 51.73%, the difference in value reached 28.27%. However, the minimum greenhouse humidity per day from the two systems has a value that is very far from the minimum greenhouse humidity to be maintained (80%), which is only ± 21%, the difference is up to 59%, even though the minimum average humidity After the use of the automation system, 0.72% was still better than the previous system. If the percentage value of the increase in the automation system's performance is calculated against the previous system in maintaining the humidity of the greenhouse, the value is 54.24% at the average humidity and 3.42% at the minimum humidity.

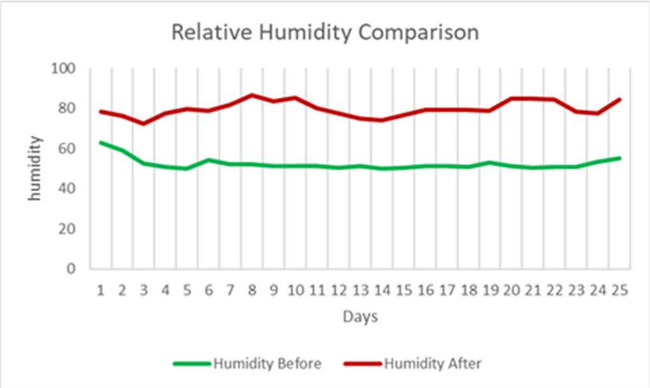


Fig. 7 Comparison between Smart Greenhouse Relative Humidity and Outside Greenhouse Relative Humidity

This may be due to the absence of a barrier on the greenhouse roof, which can reduce the intensity of sunlight entering the greenhouse so that the misting cooling system does not work optimally in maintaining the microclimate of the greenhouse.

IV. Conclusions

The proposed design interfaces with the Raspberry Pi platform and is implemented to control micro-climatic conditions in greenhouses with a web server's help. The architecture built can provide communication opportunities between users and a remote greenhouse control system. Continuous monitoring and control of environmental parameters such as temperature and humidity will be beneficial for crop production. The automation system can maintain and regulate the greenhouse microclimate to suit the optimum conditions for tomato plants every day, but performance will decrease when the sunlight intensity is high. Our misting cooling system design can be turned on automatically when the microclimate is not ideally accurate.

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