2020 20th International Conference on Control, Automation and Systems (ICCAS 2020)
Oct. 13~16, 2020; BEXCO, Busan, Korea

Light Control Smart Farm Monitoring System with Reflector Control

Jaekuk Choi[1], Dongsun Lim[1], Sangwon Choi[1], Jeonghyeon Kim[1] and Jonghoek Kim[1 *]

1 Department of Electrical Engineering, Hongik University,
Sejong, 30016, Korea
* Corresponding author: Jonghoek Kim, email: jonghoek@hongik.ac.kr

Abstract: This paper is on the implementation of a system that monitors and controls a smart farm using Arduino and DC motors. Light control in traditional smart farms uses artificial light such as LED lights to control brightness. However, this traditional method has high maintenance cost for continuously turning on artificial light. In this paper, we develop a system to control the amount of light inflow using the angle control of the reflector. Also, we monitor environmental information such as temperature, humidity, carbon dioxide(Co2), and light value for the optimum smart farm environment. The temperature is controlled using the ventilator and heater. Also, environmental data can be uploaded to the server in real-time to check the accumulated data on a chart, and we accumulate the optimal reflector angle data for more than one year. Since solar motion repeats every year, we can control the reflector according to this accumulated data. This system has been implemented as a server and mobile application that provides various sensors for environmental control, Arduino, Wemos for Wifi server upload, and a monitoring UI.

Keywords: Smart agriculture, Smart farm, IoT, Remote monitoring, Control system

1. INTRODUCTION

Smart farm refers to a farm that can "appropriately maintain and manage the growing environment of crops and livestock remotely and automatically by applying ICT to farm and livestock" mainly includes monitoring and control functions. [1] The size of the smart farm market continues to grow recently.

Smart farms currently use artificial light or receive sunlight directly in the form of greenhouses.[2][3] It controls artificial light but does not have the ability to control sunlight.[4][5][6]

Most smart farms that include IoT applications have been developed mainly for environmental monitoring.[7][8] However, these smart farms do not have the ability of automatic control.[9][10]

In this paper, we do not use artificial light, since using artificial light consumes the system power. Instead, we control the reflector of sunlight so that the optimum (depending on the plant inside the farm) or maximum sunlight can be provided for plant inside the farm. By controlling the light reflector, it has advantages of low power and a long life-circle compared to conventional smart farms that use artificial lights. As far as we know, this smart farm system based on reflector control is novel in the literature.

The proposed smart farm is distinct from that in other existing papers as follows:

1. Monitor and control temperature, humidity, carbon dioxide and sunlight.
2. The control reference values of temperature, humidity are modified remotely using the application and applied to smart farms.
3. Control the angle of the reflector to supply the optimum (depending on the plant inside the farm) or maximum light to the plant inside the farm.
4. As data accumulate in servers, data can be analyzed to select control reference value, and smart farms can be maintained in optimal condition.

Section 2 describes the Arduino and Wemos used in the system. It also describes the configuration of the proposed system and each function.

Section 3 conducts system experiments on smart farms and verifies performance.

Section 4 describes the conclusions of the proposed system development.

2. MAIN BODY

2.1 Related Theory

2.1.1 Arduino

Arduino is a board complete with an open-source, single-board microcontroller and related development tools and environments. Due to its low price and small size, it is widely used for implementing IoT devices and is also suitable for smart farms. Arduino comes in various varieties, including Uno, Mega, and Nano, depending on the purpose and specifications. The system used an Arduino Nano which is a miniaturized model with an ATmega328 processor.

2.1.2 Wemos

Wemos refers to a Wifi-enabled microprocessor unit that has added communication processor ESP-8266 to Arduino footprint. For the general-purpose model Wemos d1, it has the same specifications as Arduino Uno and allows coding and uploading using Arduino IDE. For the Wemos d1 mini used in this system, the function is the same as the d1 model, but the number of the pins and size are reduced.

2.2 Smart Farm Monitoring System

2.2.1 System Diagram

Fig. 1 shows the system diagram in this paper. Arduino transmits light of farm and angle of DC motor to Wemos. Wemos transmits Co2, temperature, humidity, light, and reflector angles to the server. The server transmits time, humidity, Co2, temperature, and light to the application.

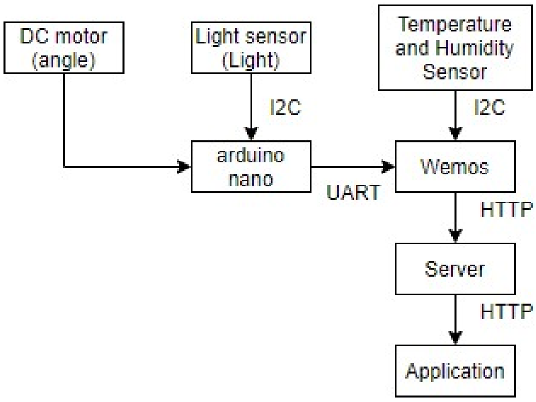


Fig. 1 System Diagram

Fig. 2 shows the reflector diagram. This figure shows the reflection of light inside the farm. The reflector controls the light onto the plant inside the farm. The sunlight is reflected by the reflector on the right side of the figure. Then, we control the reflector angle to give the optimal sunlight for the plant inside the farm.

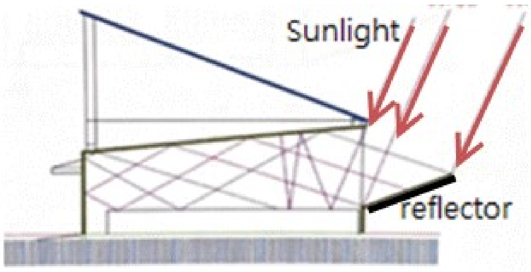


Fig. 2 Reflector diagram. This figure shows the reflection of sunlight inside the farm. The sunlight is reflected by the reflector on the right side of the figure. Then, we control the reflector angle to give the optimal sunlight for the plant inside the farm.

This system has four functions.

1. Use Arduino and DC motors to control the angle of the reflector so that the light is at its maximum or optimum for plants.
2. Collect information on the environment of light, temperature, humidity and carbon dioxide and upload it to the server.
3. The data accumulated on the server is monitored using the application. The data flow for the period of one day, one week, one month, and six months is checked using the chart.
4. The control reference for temperature of the smart farm is set remotely, and the environment is controlled using Arduino.

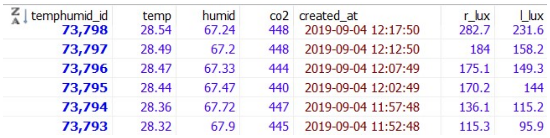
2.2.2 Sensor

2.2.2.1 Environmental sensor (SCD30)

Environmental sensors measure temperature, humidity, and Co2 (carbon dioxide) and use I2C communication. The light sensor measures the amount of light, and uses I2C communication.

2.2.3 Server upload and monitoring

2.2.3.1 Server upload



temphumid_id	temp	humid	co2	created_at	r_lux	l_lux
73,798	28.54	67.24	448	2019-09-04 12:17:50	282.7	231.6
73,797	28.49	67.2	448	2019-09-04 12:12:50	184	158.2
73,796	28.47	67.33	444	2019-09-04 12:07:49	175.1	149.3
73,795	28.44	67.47	440	2019-09-04 12:02:49	170.2	144
73,794	28.36	67.72	447	2019-09-04 11:57:48	136.1	115.2
73,793	28.32	67.9	445	2019-09-04 11:52:48	115.3	95.9

Fig. 3 Server data

When data are uploaded on the server, the upload time and sensor data are recorded on the server, as in Fig. 3 In server data, *temphumid_id* is the order of data recorded on the server, *temp* is temperature [°], *humid* is humidity [%], and *co2* is carbon dioxide [ppm]. *r_lux* and *l_lux* are the values of the light sensors constructed on the right and left sides of the smart farm, respectively. The light sensors are installed on both sides of the smart farm in order to check the light intensity inside the farm in real time.

2.2.3.2 Monitoring

Fig. 4 is the main page of the application based on a smartphone. The main page shows a list of smart farms. The page shows the most recently uploaded data.

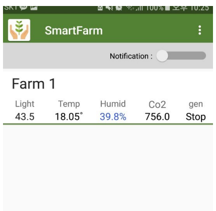


Fig. 4 Main page of the application.

Fig. 5 shows the current status screen to monitor the status of the farm. The application shows current light intensity, accumulated light over time, and the recently uploaded data. When the user presses the 'data check' button, then a list of uploaded data appears as shown in Fig. 6.

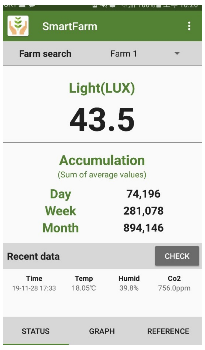


Fig. 5 Status

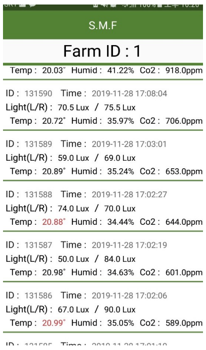


Fig. 6 Data list

Fig. 7 shows the chart of the currently accumulated data. Temperature, humidity, Co2, light data are shown in one day, one week, one month, and six month graphs.

Fig. 8 shows the screen that changes the control reference of each farm. After changing the number of the corresponding reference and click the 'Set' button, then the changed reference will apply to the farm.

Fig. 7 Graph

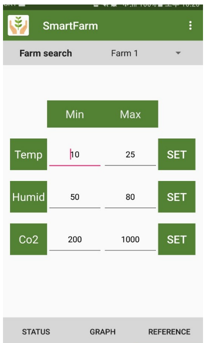


Fig. 8 Reference

2.2.4. Environmental Control

2.2.4.1 Light control

In order to obtain the reflector angle at which the maximum light is obtained, we use the light control algorithm in Fig. 9 At every hour, we run the maximum light control algorithm in Fig. 9. The algorithm in Fig. 9 finds the reflection angle which yields the largest light, by increasing the reflector angle by 10° at each step. The algorithm is explained as follows.

1. Reset the reflector angle to 0°.
2. Increase the reflector angle by 10°
3. Measure the light intensity.
4. Compare the maximum light intensity measured so far with the current light intensity. If the current light intensity is larger, then store the light intensity and the reflector angle as the maximum light intensity and reflector angle, respectively.
5. Repeat from step 2 to step 4 until the reflector angle reaches 180°.

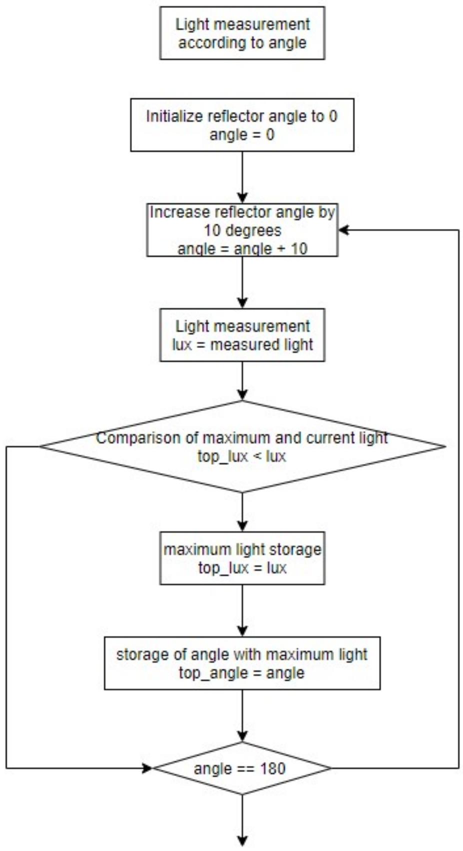


Fig. 9 Maximum light control algorithm

After running the algorithm in Fig. 9, we run the algorithm in Fig. 10, for fine search of the reflection angle of the maximum light intensity.

The light control algorithm in Fig. 10 is inspired by the P&O (Perturbation & observation) algorithm method[11]. The light control algorithm tracks the maximum light with control of reflector angle.

It is desirable that the movement of the reflector is minimized for low-power operation. Thus, the light control algorithm in Fig. 10 stops when the direction of the reflector changes 6 times continuously. The algorithm in Fig. 10 is explained as follows.

1. Set the previous light as 0, reflector rotation angle as 3°, number of continuous reflector angle changes as 0.
2. Measure the light intensity.
3. If the number of continuous reflector angle changes becomes 6, then reset that number to 0.
4. Compare between the current and previous light intensity. If the previous light intensity is larger, then increase the number of continuous reflector changes and reverse the direction of rotation. Else, reset the reflector turns to 0.
5. Rotate the reflector by the direction of rotation.
6. Store the current light in the previous light.
7. Wait for 30 seconds and go to step 2.

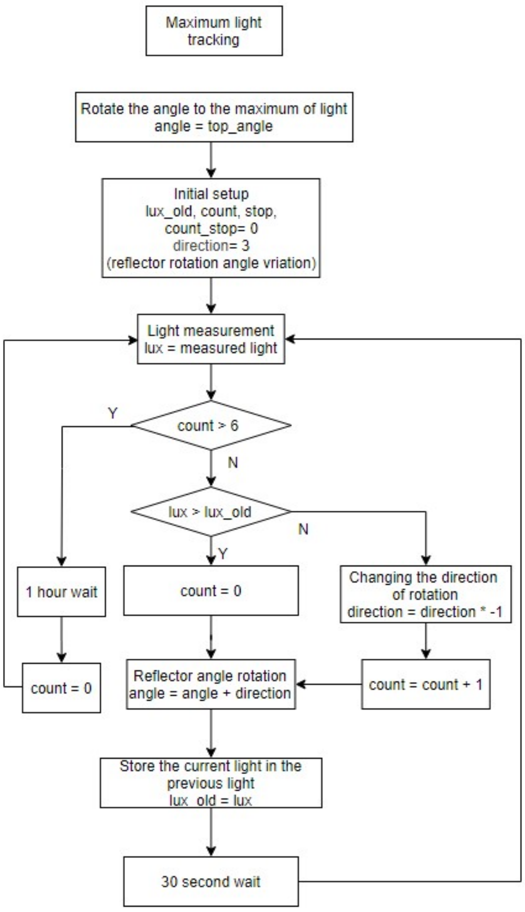


Fig. 10 Light control algorithm

In very high intensity of light, chlorophyll may be damaged, and photosynthesis is reduced. Also, the optimum light intensity of a plant may be different from that of other plant. To resolve this problem, we use the optimum light control algorithm in Fig. 11.

At every hour, we run the optimum light control algorithm in Fig. 11. The algorithm sets the optimum light as the average of the maximum and minimum light. The algorithm in Fig. 11 finds the reflection angle which yields the closest light to the optimum light, by increasing the reflector angle by 10° at each step.

After running the algorithm in Fig. 11, we run the algorithm in Fig. 12, for fine search of the optimal reflection angle. The algorithm is explained as follows.

1. Set the previous light as 0, reflector rotation angle as 3°, number of continuous reflector angle changes as 0.
2. Measure the light intensity.
3. If the current light is between the maximum and minimum light, then stops moving and wait for 1 hour.
4. If the number of continuous reflector direction changes becomes 6, then reset that number to 0.
5. Set the average of maximum light and minimum light as the optimum light.
6. Let *Ac* denotes the absolute value of the difference between the optimum light and the current light.
7. Let *Ap* denotes the absolute value of the difference between the optimum light and the previous light.
8. If *Ac* is larger than *Ap*, then increases the number of continuous reflector changes and reverse the direction of rotation. Else, reset the reflector turns to 0.
9. Rotate the reflector by the direction of rotation.
10. Store the current light in the previous light.
11. Wait for 30 seconds and go to step 2.

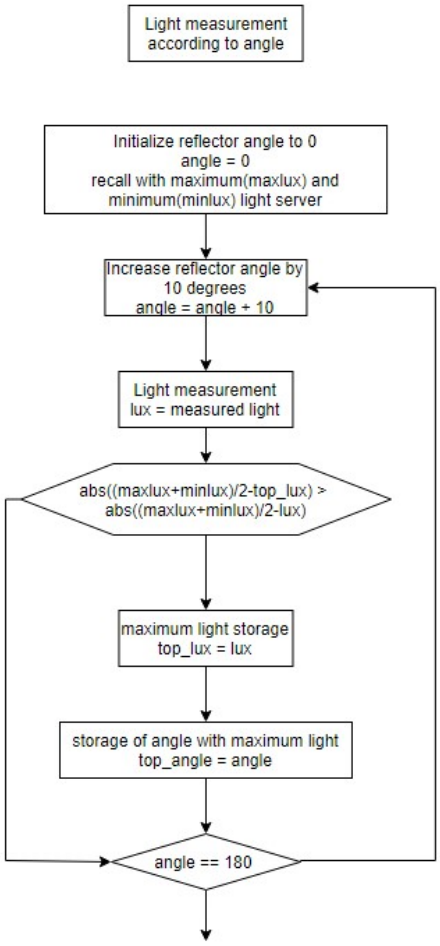


Fig. 11 Optimum light control algorithm

2.2.4.2 Temperature Control

If the current temperature of the farm is higher than the maximum reference value, then the ventilator is started according to the algorithm in Fig. 13 to control the temperature inside the farm.

3. EXPERIMENTS

3.1 Experiments environment

All experiments are conducted at the smart farm facility which is depicted in Fig. 14. In Fig. 14, two light sensors (left sensor and right sensor) are installed on both sides of the farm, and temperature & Co2 sensors are installed in the center. The reflector is installed in front of the farm. By controlling the DC motor attached to the reflector, we control the light onto the plant inside the farm.

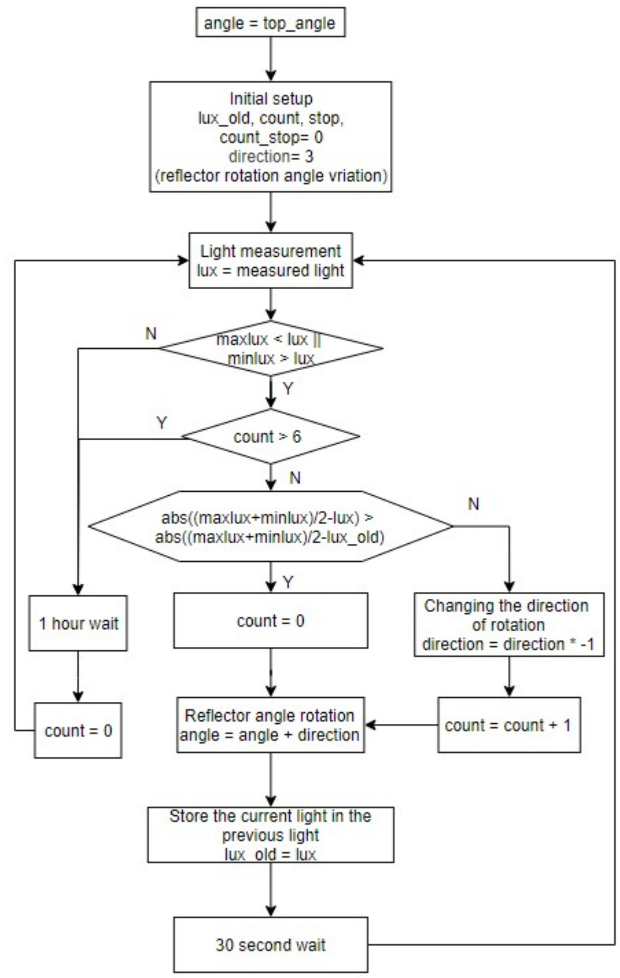


Fig. 12 Light continuous control algorithm

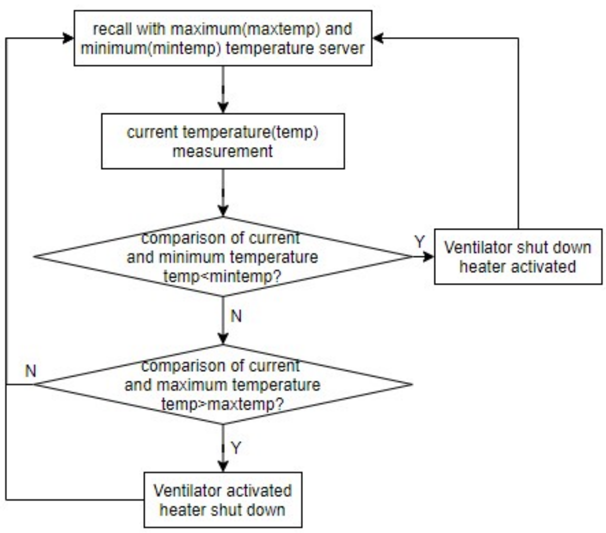


Fig. 13 Temperature control algorithm

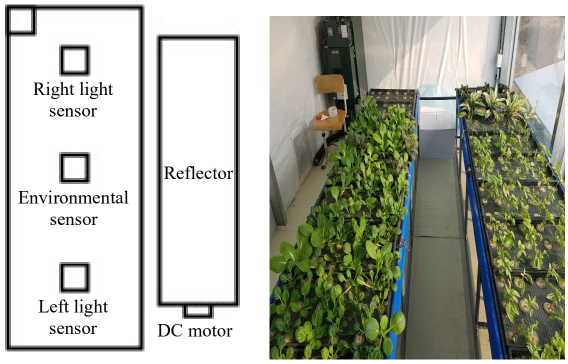


Fig.14. Smart farm structure

3.2 Maximum Light Control (Figs. 9 and 10)

- Measure the light from 02:00 PM to 03:00 PM in every minute.
- Experiments in clear weather where the light is measured at 15,000lux or more.
- Experiments when the light control system is on or when the system is off

Fig.15 shows that the light remains above 15,000lux under the light control system. If the light control system is off, then the light is not stable and is usually less than 15,000lux, as shown in Fig.16.

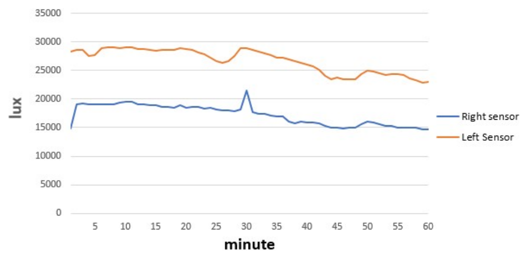


Fig.15 Light data when the light control system is on

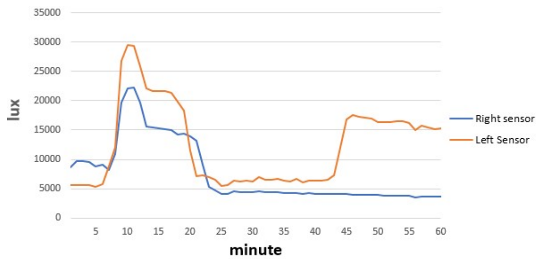


Fig.16. Light data when the light control system is off

Fig.17 shows the comparison of the average light intensity between the case where the light control system is on and the system is off.

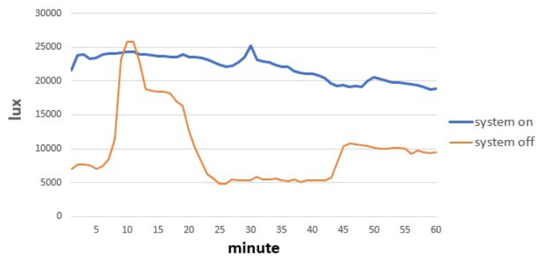


Fig.17 Comparison of the average light between the case where the light control system is on and the case where the system is off.

3.3 Optimum Light Control (Figs. 11 and 12)

● Measure the light from 08:00 AM to 02:00 PM in every minute.

● Set the minimum light to 150lux and the maximum light to 200lux.

● The x-axis of the graph is displayed in minutes and the y-axis is marked with light (lux).

Fig.18 shows that the light intensity stays between 150lux and 200lux.

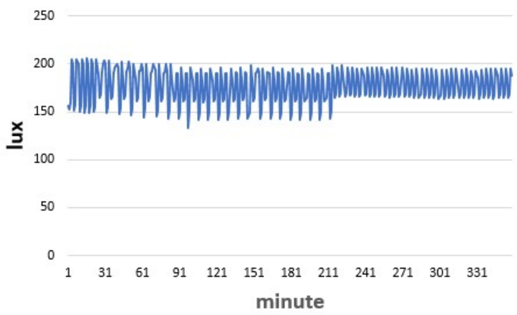


Fig18. Optimum Light Control graph

3.4 Temperature Control

● Measure the temperature from 02:00 PM to 03:00 PM at every minute.

● The temperature reference is set as follows:17~ 21°C.

● Experiments when the temperature control system is on and the system is off.

When operating the temperature control system, the temperature is maintained between 17 and 21°C. See Fig. 19.

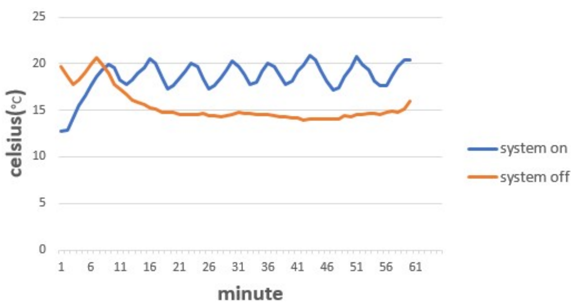


Fig.19. Comparison between the case where the temperature control system is on and the case where the system is off

4. CONCLUSIONS

This paper proposed a smart farm system to monitor the light, temperature, humidity, and carbon dioxide values of smart farms and to keep them in optimal condition.

To configure the system, the control board of Arduino and Wemos was developed. And, the measured data are uploaded to the server using the Wifi environment. In this way, we can monitor server data in real-time and check the historical graphs.

The system developed in this paper can control the light intensity by controlling the reflector autonomously. In addition, if the data are accumulated for more than one year, then the optimal angle of the reflector on each date can be predicted, allowing continuous operation without additional reflector angle control.

5. ACKNOWLEDGEMENT

This work was supported by the National Research Foundation (NRF) of Korea grant funded by the Korea government (MSIT). (No. 2019R1F1A1057282)

REFERENCES

[1] Smartfarmkorea: https://www.mafra.go.kr/english/index.do

[2] Young-Min Park, "The Arduino based Windowfarm Monitoring System", *Journal of the Korea Academia-Industrial cooperation Society VOL.19* NO.5, 563-569, 2018

[3] Siwakorn Jindarat and Pongpisitt Wuttidittachotti "Smart Farm Monitoring Using Raspberry Pi and Arduino", *2015 International Conference on Computer, Communication, and Control Technology (I4CT 2015) in Imperial Kuching Hotel*, Kuching, Sarawak, Malaysia, April 21 - 23

[4] Jennifer S Raj, "Automation using IoT in GREENHOUSE environment", *Journal of Information Technology and Digital World Vol.01/ No. 01*, Pages: 38-47, 2019

[5] Drishti Kanjilal, "Smart Farm: Extending Automation to The Farm Level", *International Journal of Scientific & Technology Research VOLUME 3*, ISSUE 7, JULY 2014

[6] Sabir Hussain Awan, "Smart Farm Intelligence Model to Uplift Farmers in Rural Pakistan ", *International Journal of Wireless Communications and Mobile Computing. Vol. 6*, No. 4, pp. 49-55. 2018

[7] M Nagaraju and Priyanka Chawla, "IoT Implementation and Management for Smart Farming", *International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075*, Volume-8 Issue-10, August 2019

[8] Jirapond Muangprathub, "IoT and agriculture data analysis for smart farm", *Computers and Electronics in Agriculture Volume 156*, Pages 467-474, January 2019

[9] Jesús Martín Talavera, "Review of IoT applications in agro-industrial and environmental fields", *Computers and Electronics in Agriculture Volume 142*, Part A, Pages 283-297, November 2017

[10] Hemlata Channe, "Multidisciplinary Model for Smart Agriculture using Internet-of-Things(IoT), Sensors, Cloud-Computing, Mobile-Computing & Big-Data Analysis", Hemlata Channe et al, *Int.J.Computer Technology & Applications,Vol 6 (3)*,374-38

[11] Mei Shan ngan, Chee Wei Tan, "A study of maximum power point tracking algorithms for stand-alone Photovoltaic Systems", *Applied Power Electronics colloquium (IAPEC) 2011 IEEE*,pp. 22-27,2011.