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Design and Implementation of the IoT Cloud Web Server System for the Control of Insect Farming Facilities

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Abstract. This paper attempted to design and implement a remote-control system based on the Internet of Things (IOT) to control the growth of insects. A user interface application was built to monitor and control the growth conditions of edible insects and a communication environment was created for IOT system-based communications. In addition, a mobile application was designed and implemented to monitor and control the growth conditions of edible insects. With the accumulation of cloud data to monitor and control the growth conditions of a small volume of edible insects, this system can be used as a database system that enables the storage of data on environmental sensor data by time series and the identification of changes in the data.

Keywords: Android Things, Internet of Things (IoT), cloud API, Insect grower control, FCM.

1. Introduction

The insect market is growing every year world-widely. Owing to the promising aspect of insect resources as the future agricultural resources such as food, functional material, and agricultural material, they are highlighted as a new way-out of agriculture and farming villages in the stagnation of agricultural income level. Also, the feed efficiency is high in case of farming, and it is free from the existing elements of environmental pollution such as pesticides, livestock excretion, and greenhouse gas, which could contribute to public value.

Many countries are actively investing in and supporting for insect industry by establishing the legal basis such as manufacturing method of microbial pesticide and an act for managing the flora and fauna, and then utilizing insect resources based on it (Yoon *et al.*, 2016). The international society including the EU is showing active movements to use insects as food resources, and each country including the Food and Agriculture Organization of the United Nations is rushing into technical researches on the practical mass-rearing of insects to solve the shortage of food. As a global nation of insect industry, Wageningen University in the Netherlands launched a project “SUPRO2” aiming for the sustainable production of insect protein for food after receiving the support fund(one million euro) from the government from 2010, and then it is researching/developing technologies related to rearing and value of insects as a source of high-quality protein.

Denmark is carrying out researches on edible insects by performing extensive researches on sustainable agriculture and food production/processing focusing on University of Copenhagen. The United States and Europe are not only investing in the development of insect industry and insect resources, but also actively supporting the facilities and equipment for the rearing/use/development of insects.

Internet of Things (IOT) network technology is used in studies on insect farming facility systems which are necessary in the insect industry. Insects in this industry are largely divided into those for food, feed, pollination, environmental cleanup, and learning and pets. In South Korea, the insect market had a total value of 168 billion won in 2011, comprised of 77.8 billion for learning and pets, 34 billion won for pollination, 9.6 billion won for natural enemies, 40 billion won for regional events, 2.5 billion for feed and medicine, and 4.1 billion won for other purposes. In 2020, however, the market has grown at 59 billion won for learning and pets, 57.5 billion won for pollination, 4 billion won for natural enemies, 254.2 billion won for regional events, 123.6 billion for feed and medicine, and 38 billion won for other purposes. Notably, demands for regional events, food, feed, and medicine are rapidly growing (Yoon *et al.*, 2016; Kim *et al.*, 2020).

The field of medicinal/edible insects in Korea has also established the institutional foundation for the production and commercialization of edible insects through the development of insect industry, enactment of Act on the Promotion/Support of Insect Industry, and registration of general food raw ingredient.

Edible insects are forecast to become highly popular as an area for the supply of a new source of protein. Insects for feed will have demands for the feed of livestock and pet animals as a source of high-protein nutrients that can be bred in large volumes at low costs. In terms of insects for pollination, with consumers’ growing demands for eco-friendly safe agricultural products, there are demands for pollen vectors for cross-pollination. Insects for environmental cleanup also attract demands for the eco-friendly processing of leftover food and agricultural by-products. In recent years, insects for learning and pet animals have been one of the fastest growing markets. With the development of new usages, this market is projected to expand continuously (Bigdata, 2015).

The Rural Development Administration has conducted researches on the use of edible insects since 2011. After scientifically verifying that there would be no problems like toxicity or harmfulness to human body, the larva of mealworm, Protaetia brevitarsis seulensis, and beetle, and Gryllus bimaculatus were registered as new food raw ingredients in 2016. After the implementation of Act on the Promotion/Support of Insect Industry in 2017, such insects are reared for various purposes like medicine & medical supplies, pet, and feed, which grabs attention as a power for new growth and increase of household income of insect farms. Especially, the Protaetia brevitarsis seulensis is produced by about 50% of insect-rearing farms, and the sales of it is almost about 56%, so that it could be the most important item in the insect industry. Even though the insect industry is continuously developing as a source of creating new income to farms in these days, such problems like petty production facilities of farms, backward rearing facilities, absence of standardized rearing system like intensive rearing, and excessive occurrence of distribution costs by individual small-scale rearing are working as limitation factors. Also, except for some leading farms, in the general rearing environment of Protaetia brevitarsis seulensis at the site of farm, it is difficult to control temperature/humidity; there is almost no ventilation, cleaning, and disinfection; the disease and pest like green muscardine are frequently occurring by the supply of contaminated feed; the grow disorder is shown in larvas, so that it is urgently needed to develop the insect smart-farm rearing system.

The present study designed and implemented a web server-based remote-control system that is based on firebase cloud messaging (FCM) and enables the expansion of small-scale IoT in an IoT remote-control systems through an Android Things application.

2. Related Researches

2.1. IoT(Internet of Things)

The dictionary definition of IoT is a network that interconnects things and spaces to form intellectual relations such as sensing, networking, and information processing in a mutually compliant manner without the explicit intervention of humans regarding three separate environmental factors of humans, things, and services. Major technologies used to implement IoT include sensor, network infrastructure, and IoT service infrastructure technologies.

Mainly used sensor technologies are expanding into areas that the five senses of humans cannot sense. Leading sensors include optical digital sensors that detect the presence or absence of objects. Moreover, analogue sensors that measure temperature, humidity, and distance are frequently used. Nowadays, sensors capable of sensing terrestrial magnetism and acceleration are embedded in premium devices such as smartphones, thereby expanding their potential. IOT-based network infrastructure technologies include Zigbee, WPAN, BcN, and PLC as well as Wi-Fi, 3G/4G/LTE, Bluetooth, Ethernet, and serial communication that are well-known as communication devices that comprise networks (Academy *et al.*, 2014; Yun *et al.*, 2012; Kim *et al.*,2014).

IoT service interface technologies refer to the role of storing, processing, and converting information. One of them is big data technology that stores, analyzes, and processes vast amounts of information obtained from various sensors. Data mining technology, which extracts valuable information from formerly accumulated data in addition to analyzing and processing information obtained from the present point, may also be part of these technologies. In addition, the domain related to privacy and information security is also included in service interface technologies (Moparthi, 2014; Lee *et al.*, 2015).

A number of IoT open device platforms have been launched for use. In the case of cloud server-type platforms, device companies establish their own IoT platforms, support the connection of products from various device manufacturers by acquiring or merging them, or promote OneM2M, OCF, and AllSeen that interconnect platforms by extending or establishing standards for the interoperation of platforms that apply correspondingly to various standards (Ryu, 2015; Nuha *et al.*, 2015).

Solutions for IoT are expanding into a whole range of industries including agriculture, banking, education, governments, health, insurance, transportation, and utility.

According to Gartner, from an evolutionary perspective of hindsight to insight to foresight, the maturity of IoT-related technologies as of the 2010s is at the second stage of the evolutionary five stages: initiating, exploratory, defined, integrated, and optimizing (Lee, 2018; ITworld, 2014).

In terms of important technologies for IoT configuration, costs arising from the server stage make hardware configuration difficult in terms of cost effectiveness. To improve this issue, the expansion of cloud-based IoT services is frequently attempted, enabling the full configuration of small-scale IoT through configuration at the terminal stage (Park and Kim,2019).

2.2. Elements to be Considered for IoT Design of Insect Farm

In the early stage of insect farm, the ordinary farms reared insects in natural environment of temporary building like vinyl greenhouse as a sideline. However, it was tough to have year-round production with frequent occurrence of damage from disease and pest, so that the farm household income was not much compared to labor. After starting the insect rearing in structure like insect rearing facilities concrete with environment control equipment like air-conditioning & heating equipment, humidifier, and dehumidifier, the output was increased through year-round production, which was led to the improved income of insect farms. However, there were some problems like poor growth and development of insects by rapid differences of temperature in case of environment control of air-conditioning & heating equipment, difficulties of even production/management by temperature differences in each part of rearing room, and occurrence of disease and pest by excessive moisture around a humidifier. The composition of rearing system through air-conditioning system of insect smart-farm rearing system and the collection of data related to growth and development are important elements for the improvement of functions. As a system of controlling the temperature and humidity set by a user at air-conditioning room and then supplying them to rearing room, the insect smart-farm air-conditioning system could produce products in uniform sizes by maintaining a certain temperature and humidity all the time with no direct effects of rapid temperature and humidity when controlling the environment with air-conditioning & heating equipment. Also, it is easy to control humidity, so that the damages from green muscardine occurred by humidity could be prevented. It would be also possible to control the concentration of CO2 by measuring the concentration of CO2 all the time and then circulating air inside the rearing room in case when the concentration is high. The environmental data could be separately collected from sensors of temperature, humidity, and CO2 in each air-conditioning room and rearing room. It has been designed to operate the environment control system suitable for differences in set-up temperature/humidity, temperature/humidity of air-conditioning room, and temperature/humidity of rearing room when inputting the set-up temperature/humidity.

3. Configuration of the Fcm-Based Android Things IoT Control System

Unlike the existing operation of IoT systems based on servers, the IoT system related to insect farming using FCM does not require huge cloud or database infrastructure. Data processing is enabled simply by handling the relatively smaller-scale messaging of sensor data in the terminal's sensor nodes (Chen *et al.*, 2018).

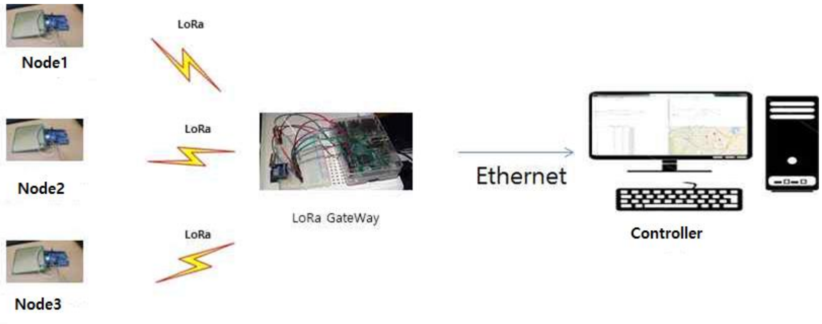

Fig. 1. Configuration of the network service system

This system is operated based on wireless communication, and the analogue entry of Raspberry Pi and digital output terminal configuration can be easily performed using basic servers to enable the monitoring of data produced by a measuring instrument accurately. In the present study, Android Things was ported to Raspberry Pi 3b+ and an Android application was configured though an analogue digital converter. Figure 1 presents a configuration of the network service system.

As shown in the configuration, sensor data detected at the sensor node stage are received by an embedded server via Wi-Fi, transmitted through an IoT cloud service, and then visualized on the Web.

4. Implementation

The current scenario of housing affordability situation of middle-income group in Sonadanga residential district is described in light of the subsequent components.

To design the configuration of a small-scale network, a server, which is capable of continuous collection of the environmental data of insect cultivation facilities, was configured by using the Raspbian system as a cloud and connecting peripheral devices through the general-purpose input/output of wireless network nodes in the microcontroller (MCU) board. In addition, for nodes, the ESP8266 Wi-Fi Web server module was installed. Using the ESP8266 module based on this advantageous setup enables the installation of a control system through a Web service without the installation of an external server. Thus, the Web service can be configured as a POST-based HTTP service by implementing a remote-control sensing system based on the IoT network.

With the recent availability of simple programing and the uploading of codes written using a USB, Arduino-based AVR devices or Raspberry Pi 3 have easily been able to expand from the domain of programming into small “things”. However, connecting these devices to the Internet requires additional modules capable of the extension of communication protocols such as Bluetooth, Wi-Fi, and LTE. ESP8266 enables simple IOT development through its integration of the MCU and Wi-Fi into one chip.

Though the MCU, RAM, Wi-Fi, and IO are embedded in the ESP8266 chip itself, their actual programing and use require flash memories, antennas, and GPIO extensions.

In terms of temperature and humidity monitoring and processing at insect farming facilities, the temperature and humidity sensor DHT11, which measures humidity and temperature levels, was used to create an environment with low rates of change even for long hours of use. The sensor’s expected specification comprised a temperature range of 0-50°C ± 2°C and a humidity range of 20-90% RH ± 5%. Figure 2 shows system for monitoring of temperature and humidity.

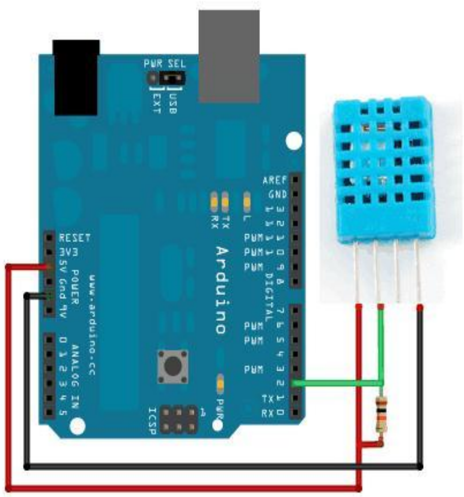

Fig. 2: System for monitoring of temperature and humidity.

In addition, the open source-based D1 system ARM board was used to collect and design sensor data. To configure the monitoring system on the growth conditions of edible insects, a cadmium sulfide illuminance sensor was used. An Internet of Small Things (IoST) Web service source code, which is directly serviced by the Wi-Fi module, was implemented through the extension of the ESP8266WiFi.h library. Furthermore, HTML-based services were created to provide Web services.

```
// Prepare the response
String s = "HTTP/1.1 200 OK\r\n";
s += "Content-Type: text/html\r\n\r\n";
s += "<!DOCTYPE HTML>\r\n<html>\r\n";
s += "<br><input type=\"button\" name=\"bl\" value=\"Turn LED ON \" onclick=\"location.href='/ON'\">";
s += "<br><br><br>";
s += "<br><input type=\"button\" name=\"bl\" value=\"Turn LED OFF\" onclick=\"location.href='/OFF'\">";
```

After the establishment of four control module logics, a test was conducted. The monitoring system on the growth conditions of edible insects was developed with a focus on its monitoring function.

To monitor sensor data on the growth conditions, a system that accumulates sensor data on humidity, temperature, and illuminance was implemented using the ThingSpeak cloud service. In doing so, an environment capable of using their databases was configured. Figure 3 shows the collection and storage of time-series data on temperature, humidity, and illuminance and the processing of these datasets for presentation.

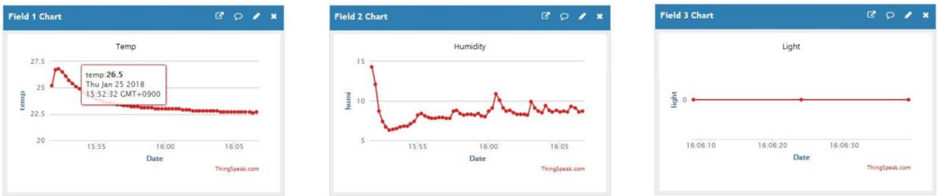

Fig. 3: Time-series graph for temperature, humidity, and illuminance data.

As shown in Figure 4, this study designed a system that can be installed at insect farming facilities and store data on the movements of insects, changes in temperature and humidity, and CO2 levels via a sensor network, and the system's prototype was built. This system can create an environment that produces an artificial effect of wintering by adjusting illuminance by time according to the growth cycle of insects in the long-term. In doing so, the system can detect remote sensing data that can affect the growth cycle of insects as well as collect and manage data through its interworking with the IoT cloud. In addition, a mobile application for monitoring the growth conditions of edible insects was implemented. The monitoring function was performed in a manner that displays data uploaded to the cloud on the mobile screen via parsing through data transmission at specific time intervals.

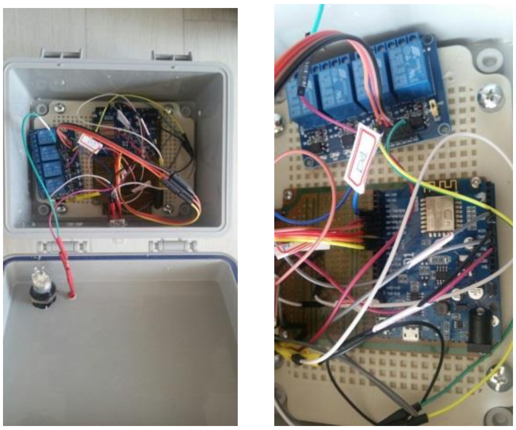

Fig. 4: Prototype of the insect growth control system.

At the stage of cloud service implementation, for ThingSpeak-related processing, the DHT library and the ESP library were used for temperature and humidity sensors by setting the API and issuing the Read key.

```
#include <DHT.h>
#include <ESP8266WiFi.h>
#include <Arduino.h>
```

```
String apiKey = "X2RZLXL9T0JOV3EW";
const char* server = "api.thingspeak.com";

if (client.connect(server, 80)) {
String postStr = apiKey;
postStr += "&field1=";
postStr += String(temp);
postStr += "&field2=";
postStr += String(humi);
postStr += "&field3=";
postStr += String(cdsV);
postStr += "\r\n\r\n";

client.print("POST /update HTTP/1.1\n");
client.print("Host: api.thingspeak.com\n");
client.print("Connection: close\n");
client.print("X-THINGSPEAKAPIKEY: " + apiKey + "\n");
client.print("Content-Type : application/x-www-form-urlencoded\n");
client.print("Content-Length: ");
client.print(postStr.length());
client.print("\n\n");
client.print(postStr);
}
client.stop();

// ESP.deepSleep(sleepTime * 10000);

/* if(milis()>100000){
soft_restart();
} */
}
```

To set up threshold standards, over 16 to 18 hours of LED lighting was allowed to provide the function of day and night, and the occurrence of hibernation triggers was prevented. Given the need to identify activity rates through the hourly analysis of activity levels by observing the activities of insects, farming facilities were set to maintain around 25°C in temperature and 50 to 70% in humidity during the farming period, while CO2 levels were set to be down at an appropriate level using an air-conditioning system. Moreover, a system was configured to enter qualitative indicators based on daily data on the ongoing conditions of insects according to their activity levels and growth conditions and convert them into data for machine learning.

The configuration of the overall system for remote control was based on overall HTTP and POST-based control through DDNS-based control, which sets up the communication port and the domain, via a gateway.

- Set up ports (up to four) for a relay control
- HTML-based Web service control
- Android-based user control and monitoring system

The system was set up to run authorized internet protocols (IPs) first. In addition, the control process was designed to enable the operation of all private IPs at indoor Wi-Fi facilities as well. For the relay control, a 5V signal control 4-channel relay was adopted to enable the control of various types of outlets. If necessary, relay control signals can be extended into input signals for other systems. The user interface (UI) environment was built by designing the Android Things layout for user control. Moreover, the cloud's route, the API key, and user information as follows were stored and processed within Android. Figure 5 illustrates the UI of the user's terminal.

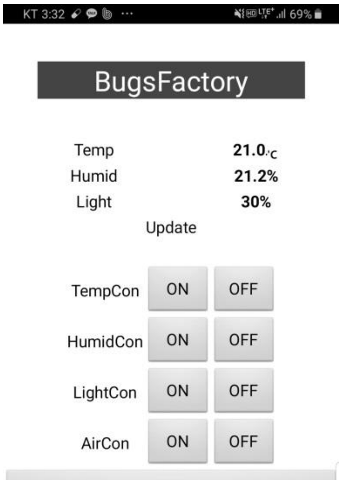

Fig. 5: UI of the user's terminal

At least three types of sensor information are extracted from the cloud, processed, and then go through extracting and parsing according to different fields. The resulting output can be displayed as character strings on a smartphone. Figure 6 indicates the database for each channel, which has been uploaded to the cloud.

{"channel":{"id":339731,"name":"D1","description":"d","latitude":"0.0","longitude":"0.0","field1":"temp","field2":"humi","field3":"light","created_at":"2017-10-02T12:37:11Z","updated_at":"2018-01-25T07:30:04Z","last_entry_id":566},"feeds":[{"created_at":"2018-01-25T07:29:49Z","entry_id":565,"field1":"22.20","field2":"15.00","field3":"723\r\n\r\n"},{"created_at":"2018-01-25T07:30:04Z","entry_id":566,"field1":"22.30","field2":"12.60","field3":"734\r\n\r\n"}]}

Fig. 6. Database by channel

The extracted lists are as follows:

Channel 1: temperature (unit: degree)
Channel 2: humidity (unit: %)
Channel 3: illuminance (unit: %)

Figure 7 shows screen shot for installation of Android application.

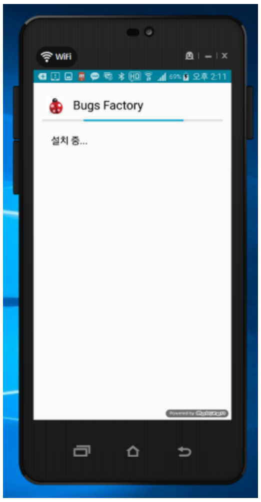

Fig. 7: Screen shot for installation of Android application

Figure 8 shows the indication of extracted temperature, humidity, and illuminance data in the user's terminal.

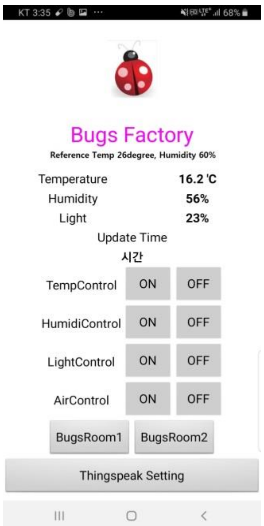

Fig. 8: Implemented Android User Interface.

5. Conclusion

In the present study, an FCM-based Web server-based remote-control system was designed and implemented, which enables the expansion of small-scale IoT in an IoT remote-control system through an Android Things application.

In the Web service, the environmental data of farming facilities were uploaded to the cloud using the Web. Once the data approach a threshold, a text message is transmitted. When vibration values that are entered into a database are visualized using the Web, insightful values can be obtained through the comparison of measured vibration values. In the open cloud server ThingSpeak, measured values and the time for their entry are stored in the database simultaneously via the Web, which makes it possible to identify changes in vibrations. This service can be used as a database that enables the storage of environmental sensor data by time series and the identification of their changes through the accumulation of cloud data aimed at monitoring and controlling the growth conditions of edible insects.

6. Acknowledgments

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