Development of IoT-Based Remote Monitoring Module for Greenhouse Environment to Facilitate Crop Growth Data Analysis

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Abstract

As the shortage of agricultural population is becoming an issue, services that remotely monitor the agricultural environment using IoT are being offered in the market. However, small- and medium-scale private farmers are unable to purchase or rent IoT equipment and monitoring tools because they have to spend their budgets on maintenance and utilities in greenhouses to support environmental management, and the construction of data infrastructure has not been widely adopted. Therefore, in this experiment, we developed an agricultural IoT that can be provided to medium and small farmers, and a module that enables collection, accumulation, and visualization of time-series data acquired from sensors. The module provides an architecture that includes multiple sensing, networking, processing, and visualization applications to keep deployment and management costs low. To demonstrate its feasibility, the proposed IoT system was built, experimentally tested, and verified in a greenhouse in Yatsushiro, Kumamoto, Japan, by intermittently monitoring temperature, humidity, carbon dioxide concentration, solar radiation, and soil moisture content in the greenhouse for two years. The results obtained confirm that the proposed IoT remote monitoring module facilitates farmers to monitor the growing environment of their crops and enables them to improve their productivity by progressively increasing their technology level.

Keywords: IoT, Agricultural, Monitoring System, visualization

1. Introduction

Smart Agri and Agri Tech are attracting attention as new forms of agriculture that utilize advanced technologies such as robotics, ICT to enable labor-saving, high-quality production [1]. One of the technologies that support this Smart Agri is the spread of the Internet of Things (IoT), whereby various "things" are now connected to the internet IoT refers to a system whereby sensors are built into various "things", which are then connected to the internet, and a large amount of data acquired via the internet It is a mechanism whereby large amounts of data acquired via the internet are stored in the cloud. This accumulated large amount of data is known as 'big data' (BD), and although BD cannot create value simply by accumulating it, new value can be created by analyzing the accumulated data [2].

In agriculture, where declining productivity due to an ageing population and a lack of bearers is a problem, there are high hopes for this IoT as a way to improve productivity with fewer people. It is desired to acquire environmental information on farms, which is a factor that changes the quality and quantity of agricultural products, and to visualize this information. In addition, one of the challenges for future development is to analyze the acquired data and weather data and utilize them as time-series data for forecasting, thereby improving productivity and ensuring the production of high-quality and stable agricultural products [3]. Here, an example of a farmer growing banana and coffee in Yatsushiro, Kumamoto Prefecture, Japan, is presented. Banana and coffee are mainly grown in tropical regions. Japan belongs to the temperate zone, and farmers across the country are searching for new cultivation methods to enable the cultivation of tropical plants such as banana and coffee in temperate Japan. Farmers in Yatsushiro City, the site of this experiment, also grow bananas and coffee and maintain a tropical environment in vast plastic greenhouses. However, in Japan, which has four seasons, temperatures vary throughout the year and it is difficult to maintain a constant environment inside the greenhouses.

However, in Japan, which has four seasons, the temperature varies throughout the year and it is difficult to maintain a constant environment in the vast greenhouses, which affects the growth and production of the plants. For this reason, many companies are introducing agricultural IoT, collecting environmental data in greenhouses and providing visualization services. However, small- and medium-scale individual farmers have to spend their budgets on the maintenance of their greenhouses, utility costs and other costs to support environmental management, and are unable to purchase or rent IoT equipment and monitoring tools, which means that the construction of data infrastructures has not become widespread. Therefore, in this experiment, we developed an agricultural IoT device that can be provided to medium and small farmers, and built a system for collecting, storing and visualizing time-series data acquired from sensors.

2. Development concept

The concept was set up as follows.

- To collect on temperature, humidity, carbon, dioxide concentration, moisture content and solar radiation in order to investigate environmental information in greenhouse from all perspectives.
- Designed to continue to operate even under severe environmental conditions and to ensure that data acquisition is not interrupted.
- Programmed to be able to be used universally at other sites, and designed so that sensors can be connected using connectors.
- Collect agricultural IoT devices that meet the above conditions using inexpensive and highly accurate sensors.

A system of IoT modules configured according to the concept is shown in Fig. 1. All sensor values are regularly collected by microcomputer and stored in storage in the cloud. The user can view the values of these sensors numerically and graphically at any time and from anywhere.

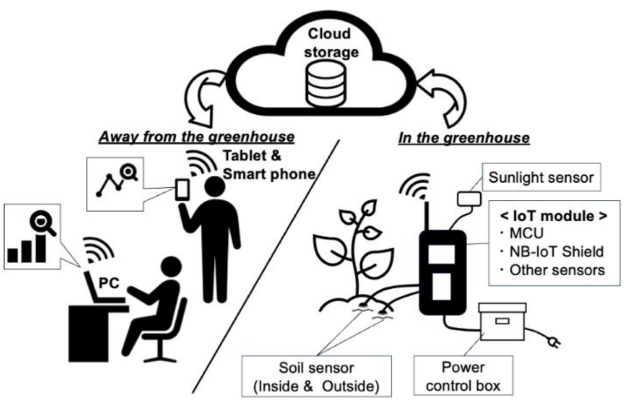

Fig. 1 System image of the IoT module

The developed IoT device is shown in Fig. 2 and the specifications are given in Table 1. As an Micro Controller Unit (MCU), the Arduino, which is also used in other smart farming systems [4], [5], was used. The developed IoT device was equipped with several types of sensors to collect data in order to investigate the environmental information inside the greenhouse from all perspectives.

In order to develop an IoT device that can continue to operate even in a harsh environment, a temperature and humidity sensor was also attached to the inside of the greenhouse, and a durability test was conducted to investigate at what temperature range the device would break down. The results showed that failures occurred at around 50 °C, so a fan was installed inside the chamber to prevent failures due to overheating of the IoT device. In addition, a Watch Dog Timer (WDT) was incorporated into the software to monitor whether the MCU program stopped or communication was interrupted, and if so, measures were taken to restart the program. By taking countermeasures in terms of hardware and software, we were able to develop an IoT device that could continue to operate even in a harsh environment.

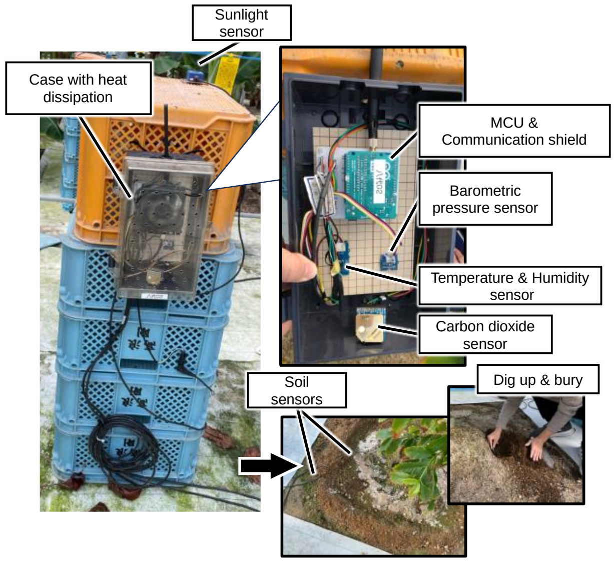

Fig. 2 IoT devices developed (being implemented in a green house in Yashiro).

Table 1 Specification of agriculture IoT module

Size (Length x width x depth)	280.5 × 170 × 130
MCU	Arduino Uno
Supply voltage	$12[V]$
Line	Long Term Evolution (LTE)
Temperature sensor	BME280
Humidity Sensor	
Barometric pressure sensor	
Carbon dioxide sensor	S-300-3V
Soil moisture censer	WD-3-W-5Y
Sunlight sensor	PVSS-03

Fig. 4 Visualization using SORACOM Lagoon
(Only some data on coffee was extracted)

3. System configuration diagram

The system configuration is shown in Fig. 3. The data acquired from each sensor connected to the MCU was A/D converted and the time-series data was stored in the data server via the LET module. The data server used SORACOM Harvest provided by SORACOM, and SORACOM Lagoon (Fig. 4) was used as the visualization tool.

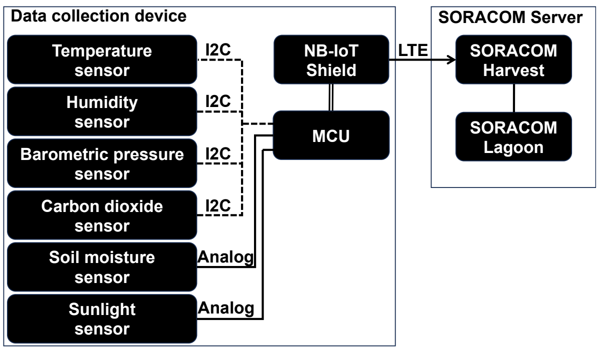

Fig. 3 System configuration diagram

4. Field experiments and time series data obtained

The developed agricultural IoT equipment was actually installed in a plastic greenhouse in Yatsushiro to monitor the growing environment of banana and coffee as shown in Fig. 5. The monitoring period started intermittently in 2021 and lasted for two years until 2023. The data interval was 15 minutes. An example of the data collected is shown in Fig. 6. This is temperature data, where temperatures inside and outside the developed agricultural IoT module were collected for one month. As can be seen from Fig. 6, sensor values were successfully retrieved and stored in cloud storage at 15-minute intervals. The sensor values also show that the internal temperature tends to be 1-5 ℃ higher than the temperature outside the IoT module, but is kept almost the same due to heat dissipation.

However, as a problem, the phenomenon of system stoppages could appear. When the system is restarted, it returns to a state where data can be continuously retrieved again. The data in which this phenomenon appears is shown in Fig. 7. The period during which the sensor values are not updated is the period during which the system is stopped. This has not yet been resolved. As a countermeasure, the system was monitored and improved so that it can be restarted remotely in the event of a stoppage. After the improvements, the system stoppages have not been reproduced, but the program is being logged so that the cause of the reproduction can be clarified.

Fig. 5 Installation of the developed IoT modules
(Right: coffee field, Left: banana field,
Top: before growth, Bottom: after growth)

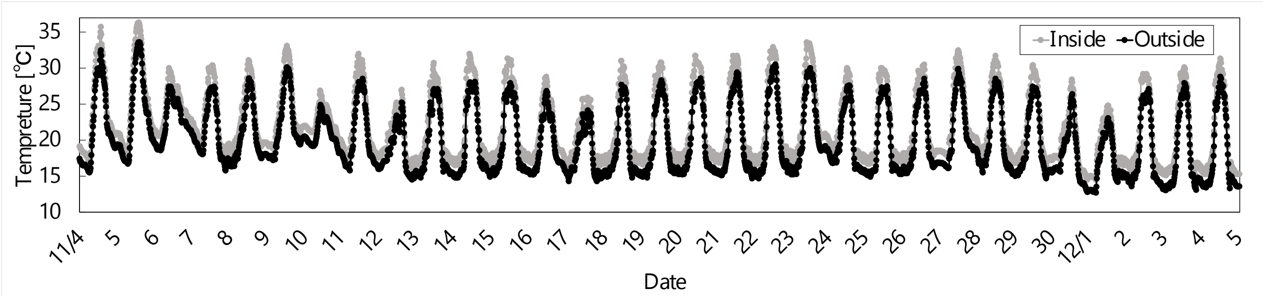

Fig. 6 Temperatures observed by IoT devices(4 November 2023 - 4 December 2023)

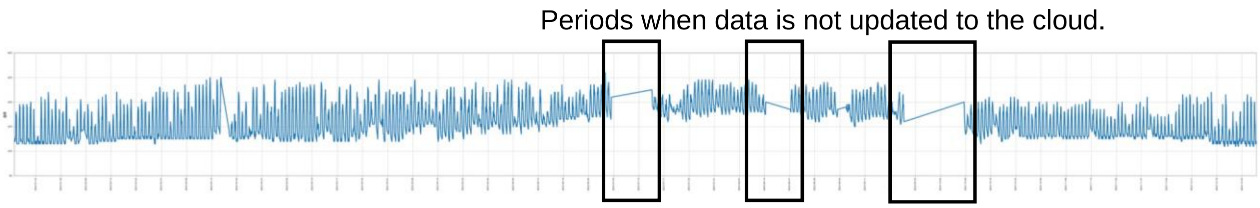

Fig. 7 Temperatures observed by IoT devices(17 January 2022 – 28 December 2023)

5. Conclusion

In this study, an IoT device for agriculture was developed and actual field observation experiments were conducted in greenhouses. As a result, a device with the following functions was developed.

- To continue to operate normally in greenhouses where the humidity is above 90% and the temperature exceeds 30°C.
- Data is uploaded to the cloud every 15 minutes and can be immediately visualized.
- The device can observe multiple parameters (temperature, humidity, barometric pressure, Sunlight, soil moisture and carbon dioxide concentration in the air).
- Robust against communication errors.

In the future, the durability of the system will be increased by improving the modules so that the system can run without stoppages for a long period of time.

Acknowledgements

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References

1. J. Pretty, "Agricultural sustainability: concepts, principles and evidence", Philosophical Transactions of the Royal Society B: Biological Sciences, Vol. 363(1491), 2007, pp. 447-465.
2. O. Elijah, T. A. Rahman, I. Orikumhi, C. Y. Leow and M. N. Hindia, "An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges," in IEEE Internet of Things Journal, vol. 5, no. 5, 2018, pp. 3758-3773.
3. M. R. Bendre, R. C. Thool and V. R. Thool, "Big data in precision agriculture: Weather forecasting for future farming," 2015 1st International Conference on Next Generation Computing Technologies (NGCT), Dehradun, India, 2015, pp. 744-750.
4. V. K. Shukla, R. S. Nair, F. Khan,"Chapter 13 - Smart irrigation-based behavioral study of Moringa plant for growth monitoring in subtropical desert climatic condition", In Intelligent Data-Centric Systems, AI, Edge and IoT-based Smart Agriculture, Academic Press, 2022, pp. 227-240.
5. E. Ogunti, "IoT Based Crop Field Monitoring and Irrigation Automation System", International Journal of Innovative Science, Engineering & Technology, Vol. 6 Issue 3, 2019, pp. 124-129.

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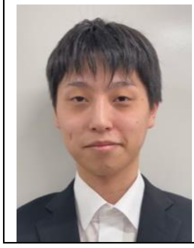

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