# Semi-Automated Mushroom Cultivation House using Internet of Things

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**Abstract.** *This research presents an application of the internet of things (IoT) technology. The technology is responsible for checking the temperature and humidity in a mushroom cultivation house and the operation of the IoT control box. It is a semi-automated system that does not rely on farmers' labor. The system can be checked and operated through an application that is installed on the farmer's smartphone. In the case of offline operation, the system can be controlled manually by farmers. We designed a software and control system for the IoT control box with concern for the needs of farmers. Therefore, we can develop a suitable IoT control box that can be following farmers' needs. The farmer used the application for four months before their satisfaction was evaluated. The results showed that the semi-automated system obtained a high satisfaction rate towards system. However, when asked about "The value in using the internet of things technology to control the mushroom cultivation," The satisfaction was on level 4 because of the high investment cost, including monthly internet cost. That cost might increase the overall production cost. If farmers want to reduce the monthly internet cost, the application architecture will cut the data transmission process via the cloud-connected to smartphones. The application is designed to be controlled through the IoT control box. The control system will be able to work automatically and manually.*

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## 1. Introduction

Fast technology development and supporting policy from the government encourage innovation, leading to Thailand's 4.0 era [1]. As a result, researchers have invented and developed devices that can communicate and connect to the Internet, called the Internet of Things (IoT). The IoT consists of devices for receiving and transmitting signals. IoT means a device is enabled to communicate with another device through various ways, for example, LAN, WIFI, Bluetooth, radiofrequency, and LoRa. These ways help us to control devices for any operation and check the information from a distance. Data will not be lost because it can be stored in an external database [2].

When devices connect to the internet, the IoT devices connect a device with another. This function can also be adapted to various industries [2]–[4]. In 2020, at least 50,000 million IoT devices will be created [3]. Technology is rapidly expanding. The expansion of the technology derived from the development and implementation of internet devices in many industries, for example, transportation, commercial business, health and medicine, intelligent traffic networks, intelligent electricity networks, industrial measurement and control, intelligent building control systems, intelligent cities, energy supply management, intelligent wearable devices, communication between cars, and intelligent agriculture systems.

The IoT technology helped farm management, e.g., temperature and humidity checking, determination of pH in soil and water, watering, fertilizing, and harvesting for agricultural work. The technology is called smart farming. Pantawong and Ranokpanuwach [6] designed automatic hydroponics houses in which an Arduino Mega board controlled all devices. Likewise, Ranokpanuwach [7] used Arduino to control all devices. The Raspberry Pi and camera were used to photograph vegetables to take pictures and analyze by deep learning for monitoring vegetable growth. Tanaram et al. [8] claimed IoT could be used for agriculture, e.g., 1) An automated system was used for receiving data from various sensors and actuators. Then, the system sent the data to the cloud for storage. 2) A system analyzed and made decisions using the stored data on the cloud and sent command signals to the devices on the farm. Both systems were automated systems that were reduced the amount of labor and work hours.

The study of IoT technology for monitoring temperature, humidity, and watering devices in a mushroom plant is now described.

Paka et al. [9] developed a temperature and humidity control system suitable for mushroom growth in a mushroom house using automatic water distribution. There were temperature and humidity measuring devices in the mushroom house which sent signals to the temperature and humidity control unit. The microcontroller program was set for retrieving the temperature and humidity values from measuring devices. When the values retrieved from the device do not match the target values, the control system will send a signal to the operating system that controls water supply through a water pipe and the sprinkler designed to distribute water throughout the mushroom cultivation area.

Ranokpanuwach [7] designed a cloud-based service for measuring and automatic plant watering. The system pours water on the soil by relying on moisture values. This research used cloud computing services, which is one of Amazon's services. The system included 1) a wireless sensor network for soil moisture measurement, 2) a gateway for water pump control and automatic watering 3) Amazon's service is the server to provide information services and display information. It can show both historical and real-time data.

Fongngen et a., [1] applied the IoT device to control oyster mushroom farms. The demonstration of a mushroom cultivation house had 3 meters wide, 4 meters long and 3 meters high. It was small and making it easy to move. The circuit that controls the operation consisted of temperature and humidity sensors, NodeMCU controller type NCP3008 for a processing device to command the relay device. The processing device controlled the operation of the water pump, ventilators, and heater. All control devices were packed in a waterproof case outside the house. So, they checked the information retrieved from the sensor in real-time and transmitted data through the NETPIE framework and the Blynk application.

This research has used the IoT device to control the workload of mushroom cultivation houses. We surveyed the needs of farmers at Tam Yae Community Mushroom Cultivation Group, Na Sinuan Kantharawichai, Maha Sarakham, Thailand. It was possible to receive useful information about growing up mushroom leading to suitable development for the IoT Control Box. Moreover, the surveyed data were beneficial for farmer's needs. The IoT control box consisted of the DHT22 sensor for checking the temperature and humidity values. Then it sent the information to the Blynk application on a smartphone that had an IoT platform installation. Farmers can check the information at any time they want. In addition, farmers can also control a solenoid valve to watering mushrooms using the smartphone device. The application was designed for the controlling valve to be open or closed. The control system also had an automatic function to reduce farmers' labor costs in data validation and control working in the mushroom plant.

## 2. Research Methodology

The research methodology in this article is as follows:

### 2.1 Mushroom Cultivation House Observation

Mushroom cultivation enterprises were surveyed at Tam Yae community located at 122, Moo 24, Na Sinuan, Kantharawichai, Maha Sarakham, Thailand. The survey found that the farmers have four houses, sized 4 meters wide, 8 meters long, and 2.30 meters high. The gable roof consisted of black plastic. The ground floor was designed to be soil for moisture preservation in the house and the airflow (see Fig. 1). Each house has been divided into two sides (see Fig. 2) to increase the space for arranging mushrooms.

**Fig. 1** Mushroom plant

**Fig. 2** the mushroom plant is divided into two parts

Ventilation in mushroom cultivation houses is important because each mushroom release carbon dioxide. High levels of carbon dioxide influence productivity and mushroom shape. A house with low airflow will result in low productivity, distorted and small-sized mushrooms. Therefore, the mushroom house should have a good ventilation system to remove carbon dioxide. For the harvest, farmers will collect mushrooms from midnight until 01.00 and at 05.00 because these are suitable times when the mushroom are mature.

The mushroom shelf looks like an amphitheater. The bottom of the shelves is approximately 15-30 centimeters above the ground. Mushrooms were put on layer over layer and high enough to use farmers' hands to catch them for harvesting, as shown in Fig. 1 and Fig. 2.

We surveyed a time to supply water to mushrooms from the farmer. In general, farmers supply water twice a day at 06:00 and 17:00. Each watering period usually takes 10 minutes. If the house temperature is over 30 $^{o}$C, the farmers would add an extra watering period at 12.00. The appropriate temperature in the mushroom cultivation house is between 25-30 $^{o}$C and humidity 70-80%. The watering system was designed to spray with a spray nozzle, as shown in Fig. 3. At the same time, the system must not allow water to penetrate the mushroom. However, the house must have a device for measuring humidity and temperature, as shown in Fig. 4.

From the mushroom house survey, we concluded that one set of the IoT control box could control the DHT22 device and four sets of solenoid valves. Each house is required to use only one DHT22 device and 1 set of solenoid valves.

**Fig. 3** Water sprayers used in the mushroom plant

**Fig. 4** Water sprayers used in the mushroom plant

Therefore, the IoT consist of the following parts:

- 4 sets of DHT22
- 4 solenoid valves
- 1 IoT control device including,
    - NodeMCU for receiving and sending data via the internet
    - Arduino Nano V.3 to control the IoT equipment
    - LCD screen to show the device status
    - Power supply
    - Relay, type 4 channels
- Smartphone application – Blynk Application

## 2.2 Design of the IoT Systems for Mushroom Cultivation House

The After surveying the mushroom cultivation house, we designed the IoT control unit. The connection of devices and the internet were as follows:

1. Arduino Nano V.3 connection with a DHT22 sensor is shown in Fig. 5.

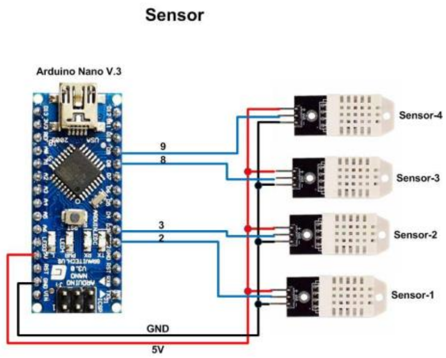


**Fig. 5** The circuit connection between Arduino Nano V.3 and DHT22

2. Arduino Nano V.3 connection with LCD screen (see Fig. 6).

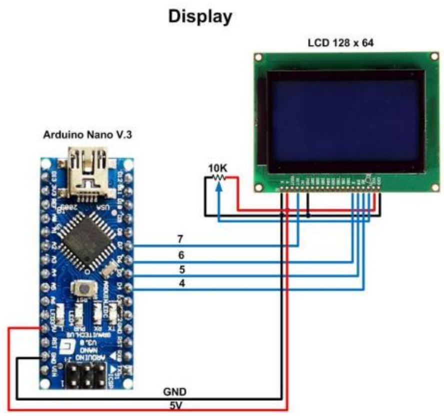


**Fig. 6** The circuit connection between Arduino Nano V.3 and LCD

3. Arduino Nano V.3 connection with Relay for controlling the solenoid is shown in Fig. 7.

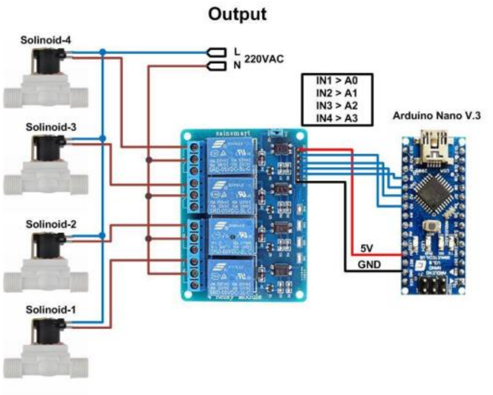


**Fig. 7** The circuit connection between Arduino Nano V.3 and relay for control solenoid valve

4. Arduino Nano V.3 connection with NodeMCU V.3 in order to receive information and send the information to the smartphone via the Blynk application (see Fig. 8).

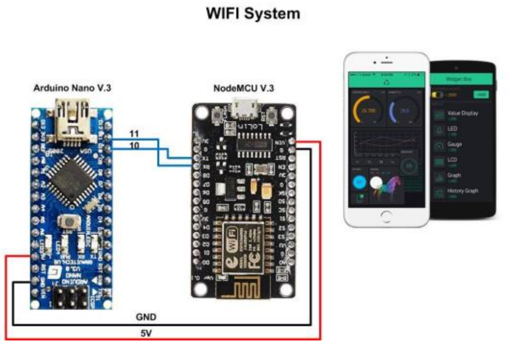


**Fig. 8** The circuit between Arduino Nano V.3 and NodeMCU V.3, The data sent from the NodeMCU V.3 to Blynk application via the internet

## 2.3 Installation of the IoT Systems for Mushroom Cultivation House

We installed the IoT control boxes at the front of the owner's house area, near the WI-FI router, to reach a strong signal and easy connection. The IoT control box for the mushroom cultivation house is shown in Fig. 9 and Fig. 10.

**Fig. 9** The IoT control box

**Fig. 10** The circuit connection of the IoT control box

The IoT control box was connected to the solenoid valve device by cable for sending the order directly from the IoT control box and smartphone application. Solenoid devices with water distribution systems are shown in Fig. 11.

**Fig. 11** Example of installing a solenoid to a water system

## 2.4 Designing Application to Control the IoT for Mushroom Cultivation House

For the smartphone application, we proposed to use the Blynk application. We programmed that allow all sensor data to operate through the cloud system by sending sensor data to Blynk's server. Then the Blynk's server was sent all data to display in a smartphone application, as shown in Fig. 12.


**Fig. 12** The Blynk application used for controlling the IoT control box

In Fig. 12, Blynk's program could show the status of the IoT control box (Online/offline). It also could show four humidity values, temperature values, and solenoid valve status (ON/OFF). If we used the manual control, we could set a time for watering control. Further, we can set it as 06:00 and 17:00. At the bottom of the Blynk application, we could push the ON/OFF buttons to water manually.

## 3. Results of the Experiments

### 3.1 Installation of IoT for the Mushroom Cultivation House

We installed and tested the first version of the IoT control box (see Fig. 13) for the operation and testing of the control system. The first software version could not be controlled via smartphone. It sent the data from the IoT control box to the NETPIE platform. Notwithstanding, the owner can open a web browser from the smartphone to check the data, such as temperature and humidity, sent from the control box.

**Fig. 13** Installing the first version of the IoT control box for mushroom plant

The first version of the IoT control box could only used in automatic operation. The inquiries from mushroom farm owners said they wanted a control system with an automatic watering that works when the temperature and humidity are lower than specified values. Therefore, researchers developed an automatic control system that received humidity and temperature values from the DHT22 sensor. The problem, in this case, was that the temperature is always higher than 30 $^{o}$C, the IoT control box sent watering orders unnecessarily. That might cause damages to the mushrooms.

The next step was using the results from the experiment to improve the software and devices to match the mushroom farm owners' needs and reduce the damage in the productivity process.

The second version of the IoT control box can be commanded in two ways:

1) **Automatic system**: The automatic system is automatic watering at specific times. In general, mushrooms must be watered in the morning and evening. The farm owner can require watering as they wish. The system can also display the working status, for example, water valve operation, temperature, and humidity. Those data are sent via the cloud to the owner's smartphone. Nevertheless, the Blynk application must be installed on a smartphone for real-time data checking. Blynk application is shown in Fig. 14.

**Fig. 14** Example of the second version, The IoT control box is controlling using the Blynk application installed on the smartphone

2) **Manual system**: Manual system is the watering control via the IoT control box and smartphone.

### 3.2 Watering System Improvement

Because the solenoid valve device may be damaged at any time, and if the solenoid valve is damaged, the control box will not send any command to water the mushroom. Therefore, the watering system was adjusted to make it easy to work if the solenoid valve is damaged. Researchers added a manual valve to use in case of the solenoid valve is damaged. Fig. 15(a) showed the first version of solenoid valve installation, which cannot be commanded when the valve is damaged. Fig. 15(b) showed the improvement by adding an on/off manual water valve.

(a) (b)

**Fig. 15** The water system of the mushroom plant: (a) Installing the solenoid valve into the watering system and (b) modified the watering system

## 3.3 Test the Operation of IoT for the Mushroom Cultivation House

The operation of the IoT control box was designed to be able to work automatic and manual modes.

1) **Automatic Control can be tested by**

- Determining the watering time: The watering time can be set by the Blynk application on a smartphone. Two times per day were set by the mushroom farm's owner. They set at 06:00 and 17:00. The test showed that the IoT control box could command the watering at the correct time.
- Checking the temperature and humidity: The temperature and humidity can be checked from the Blynk application and also checked from the LCD screen on the IoT control box. We compared the values which were obtained from the DHT22 sensor and thermometer in the farm. The result showed that temperature and humidity from both devices have no different.
- Checking valve operation: Valve operation can be checked from the Blynk application and the LCD screen at the IoT control box. The valve status can be ON/OFF. If the valve is opened for watering, the status will be ON, and if the valve is closed, that means the user stopped watering, the status will be OFF. Status was showed correctly in real-time.

2) **Manual Control can be tested by**

Watering control can be commanded from the Blynk application and controlled via the IoT control box. From the test, the water valve can be promptly controlled by application and control box.

The water control system for mushroom houses works both automatically and manually. If the system is unable to connect to the internet, the temperature and humidity data will not be checked or commanded via Blynk. We designed a system that can be controlled the control box in offline mode. Therefore, the watering system in the mushroom house still works even in offline mode.

## 3.4 Measuring the Satisfaction from Mushroom Farm Owners

The development of the IoT device was used as a temperature and humidity controller in the mushroom house. After the installation, the problem with the first software was that the NETPIE platform works via a web browser. This platform is not convenient for mushroom owners because they have to remember the URL, username, and password. The system was automatic and the NETPIE was only for checking the status of the control box. It cannot send the watering command. (NETPIE now can be installed on the smartphone.) Therefore, we explored problems and comments from mushroom farm owners for improving the second software version. This version used the Blynk application, which must be installed on a smartphone (iOS and Android system). The system was designed in two types, automatic control and manual control. Moreover, it can work in offline mode, which was convenient for the mushroom farm owner because they did not remember the URL, username, and password. In automatic mode, the farm owner could set a specific time to water the mushrooms.

From the experiment, automatic watering based on temperature and humidity is unsuitable for oyster mushrooms because oyster mushrooms have a high growth rate. Farm owners can harvest oyster mushrooms every day. So, if we use automatic watering while mushrooms are growing, the mushroom might be damaged and cannot be sold.

After the experiment, the farm owner wishes to require watering only two times each day (06.00 and 17.00). If there is heat and low humidity in the house at any time, the owner can check the information and then send orders via smartphone. This method will prevent mushrooms from damage which influences the quality of mushrooms for sale.

For one mushroom house, the owner can produce about 20-25 kilograms of oyster mushrooms, which spent time production period of 5-6 months. Then, the house must rest for one month to clean and kill fungi before starting the next period.

After improving the software in the second version, the farm owner tested it for four months. Then, satisfaction was evaluated for three farm owners. The result indicated that the mushroom farm owners were satisfied with the control box and the application because they can check information and control watering in real-time, as seen Table 1.

| Satisfaction | Average | Levels of satisfaction |
|---|---|---|
| 1. The suitability of the internet of things technology applied to control the mushroom plants. | 5 | Very satisfied |
| 2. The satisfaction of the use of internet of things technology to control the mushroom plant. | 4.67 | Very satisfied |
| 3. Design of mobile application is easy-to-use. | 5 | Very satisfied |
| 4. Learning and adapting to using the internet of things technology to control the mushroom plant. | 4.33 | Satisfied |
| 5. The value in the use of the internet of things technology to control the mushroom plant. | 4 | Satisfied |

**Table 1** The satisfaction of the mushroom plant owners toward the use of internet of things technology to control the temperature and humidity of the mushroom plant

It can be seen that the satisfaction at the "satisfy" level in Learning and adjusting using the IoT technology to control working in the mushroom house. Value for investment for bringing IoT technology in mushroom house as follows:

1) Learning and adjusting the IoT technology to control working in the mushroom cultivation house. Due to the daily life of mushroom cultivation owners, they have a high workload, e.g., making mushroom boxes, harvesting mushrooms, and selling mushrooms. So, there is less time to check the information which is sent from the control box. The application was designed to be easy to use and understand.

2) Value for investment for bringing IoT technology in mushroom cultivation house. The cost of equipment is quite expensive. It is not suitable for a mushroom owner with only 1-2 houses, but it is a worthwhile investment in a big mushroom farm.

## 3.5 Development Costs

The development cost of The IoT Control Box is estimated at 4,690 THB, as shown in Table 2.

| Item No. | Name of Item | Price (Baht) |
|---|---|---|
| 1 | NodeMCU V3 | 150 |
| 2 | NodeMCU Shield | 150 |
| 3 | Arduino Nano V3 | 150 |
| 4 | Arduino Nano Shield | 100 |
| 5 | DHT22 | 150 |
| 6 | Solenoid Valve | 440 |
| 7 | Power Supply 5V | 150 |
| 8 | 4 Channel Relay Module 5V 10A | 100 |
| 9 | Connector and electric wire | 1,000 |
| 10 | LCD Module | 200 |
| 11 | Plastic Box | 600 |
| 12 | Other Equipment | 1,500 |
| | **Total** | **4,690** |

**Table 2** The costs of the IoT control box

## 4. Conclusions

Installation of the IoT control box for the mushroom house was located at Tam Yae Mushroom Community Enterprise Group, No. 122, Moo 24, Nasinuan, Kantharawichai, Maha Sarakham, 44150, Thailand. The mushroom house has 4 meters wide, 8 meters long, 2.30 meters high. The black plastic was used to cover the grass roof. The wall of the house was made from thatch. The floor was made of soil for keeping humidity in the house. There was high ventilation in the mushroom house. The control box was not installed at the mushroom house, but it was installed in the owner's house near the mushroom house.

In general, farmers supply water to mushrooms two times a day at 06:00 and 17:00. If the temperature of the mushroom house is over 30 $^{o}$C, the farmers would add a watering period at 12.00. The appropriate temperature in mushroom cultivation houses is between 25-30$^{o}$C, humidity 70-80%. We have designed the IoT control box with both manual and automatic systems. The farmers can control watering by controlling via smartphone. Furthermore, farmers can check the temperature and humidity through the smartphone at all times.

The farm owner has tested it for four months. Then, satisfaction was evaluated from 3 farm owners. The result found that the owner of the mushroom house was very satisfied with the IoT control box. The use of IoT technology was appropriate, resulting in satisfaction with the system. The application was also easy to use, e.g., checking the information through the smartphone at any time and watering system via smartphone. The system obtained very satisfied with learning and adapting to use IoT technology. However, due to the high investment, it may not be suitable for mushroom farms with only 1-2 mushroom houses. The additional monthly cost is internet cost which the farmers need to pay at least 500THB per month.

We proposed the semi-automated mushroom cultivation house using IoT technology. The IoT technology was decreased the amount of labor and work hours because the farmer could monitor the temperature, humidity, and solenoid valve status from the smartphone application. On the other hand, the conventional technique allowed the farmer to monitor the temperature and humidity data only when the farmer visits the mushroom cultivation house. So, the farmer could not go far away from the cultivation house.

In this case, the IoT control box sent data directly via the cloud to a smartphone. Therefore, the data would not be kept in the database. It is unable to process historical data. If we need data for analysis, the data must be sent to the server computer to store data into the database. Then, we might use machine learning algorithms for further analysis.

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