An automated monitoring and environmental control system for laboratory-scale cultivation of oyster mushrooms using the Internet of Agricultural Thing (IoAT)

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ABSTRACT

This research paper presents an automated system for controlling and monitoring the cultivation of oyster mushrooms in a laboratory facility. The system uses an Internet of Things (IoT) based approach to automate the entire process. The main objective of this system is to make indoor mushroom cultivation easier and cost effective. The proposed system has proved to be very effective in saving labor cost by automatically monitoring and controlling the environment. Moreover, the proposed system has a real time update and monitoring feature which helps the grower to take immediate action. This paper provides a detailed insight into the project, including the development process, automation system, hardware setup, technical specifications, and results achieved after successful implementation.

CCS CONCEPTS

• **Computer systems organization → Embedded systems**.

KEYWORDS

Smart Agriculture, Indoor Cultivation, Mushroom Cultivation, Agriculture IoT, Automation, Smart Farming, Internet of Agricultural Thing, IoAT

ACM Reference Format:

Md. Ariful Islam, Md. Antonin Islam, M. Saef Ullah Miah, and Abhijit Bhowmik. 2022. An automated monitoring and environmental control system for laboratory-scale cultivation of oyster mushrooms using the Internet of Agricultural Thing (IoAT). In *2nd International Conference on Computing Advancements (ICCA 2022), March 10–12, 2022, Dhaka, Bangladesh.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3542954.3542985

ICCA 2022, March 10–12, 2022, Dhaka, Bangladesh

ACM ISBN 978-1-4503-9734-6/22/03…$15.00
https://doi.org/10.1145/3542954.3542985

1 INTRODUCTION

The limitations of IoT application layer protocols in transmitting/receiving messages as well as the different IoT infrastructures (Cloud, Edge, Fog) complicate the development of smart IoT applications [1, 4, 12]. Current smart IoT applications are unable to adaptively learn from other smart IoT applications due to these obstacles [15]. The aim of this research is to use IoT technology based on wireless sensor networks (WSN) to combine agricultural cultivation. Agriculture has evolved technologically in recent years, and some farmers have started to use information technology based on the Internet of Things (IoT). This study focuses on oyster mushrooms as cultivation objects to make indoor mushroom cultivation easier and cheaper through the proposed system.

People continue to explore various aspects of the agricultural sector to meet their food needs. With the advancement of technology in various fields, people are encouraged to combine agriculture and technology [26]. One of the approaches is to automate the agricultural system using the Internet of Things, also known as Internet of Agricultural Things (IoAT) [24]. The proposed automated system is suitable for use in this field as it can help in data collection, automation and monitoring among others [2, 28]. People are busy with more and more tasks and the value of time is increasing, so this kind of automation system is a great way to save time. This kind of automation system can also help lay the foundation for the future of the hydroponic farm model [11]. Before the harvest season begins, oyster mushrooms must be grown under strict conditions. These strict conditions, such as temperature and humidity, are difficult to track and control on an hourly basis, so farmers must manually check each growing process [7]. For this study, the oyster mushroom was chosen as the experimental subject for cultivation. There are three different types of oyster mushrooms, namely yellow oyster, tree oyster and Indian oyster. In practise, automation systems, i.e. various forms of industrial automation, are already integrated in many sectors and handle everything from manufacturing to telephone exchange management [14, 20].

In this study, an attempt is made to produce mushrooms with minimum human intervention while maintaining the performance, reliability and perfection of a human-influenced cultivation process. For an ideal cultivation environment, twelve factors are considered which are called ideal parameters [22]. Table 1 shows the ideal parameters for mushroom cultivation.

Table 1: Ideal parameters for mushroom cultivation

Sl	Parameter Name
1	Temperature
2	Humidity
3	Co2 Level
4	Light
5	Air Exchange
6	Treatment
7	Nutrient
8	Particle Size
9	Moisture
10	pH level
11	Electrical conductivity
12	Oxygen

Among the parameters listed in Table 1, three important parameters are automated in the proposed system, namely temperature, light and humidity. However, most of the studies on automation of mushroom cultivation only deal with temperature and humidity [5, 13, 16, 27]. Moreover, a mode switching function is added in the proposed system to allow the user to select different options for different types of mushrooms. All three types of oyster mushroom cultivation are included in the proposed system. These parameters are stored in a software variable and a looping function compares them with the ideal parameters for the selected mode as well as the current values for temperature, humidity and light. If the device detects an unbalanced condition compared to the ideal parameters, it automatically takes action to correct this [23]. The proposed system provides communication link through the internal WiFi network. The system also provides the facility to control the light intensity through loop function. An alarm is triggered to alert the user and a notification is automatically sent through the online notification feature. To monitor and manage the real-time data generated by the proposed system, a user interface and system automation control is developed as a dynamic web application and integrated with our IoT system.

2 RELATED WORKS

Due to the worldwide demand & possibility, much research has been done on mushroom cultivation. The environmental friendliness and the use of agricultural waste (e.g. sawdust, husks) for the growing medium made it more sustainable [3]. All these research works have already proved that the IoT system can ensure high yields in mushroom cultivation. Temperature and humidity are the two parameters that need special attention in mushroom cultivation [3]. Conventionally, mushrooms are grown indoors under the conditions of the natural environment. Temperature and humidity are controlled by manually spraying the soil with water to maintain the indoor climate. However, manual monitoring of humidity and temperature is tedious and time consuming. To overcome this limitation, researchers have integrated IoT into the entire urban growing system.

In the work mentioned in [21], Riskiono et. al. used wireless sensor networks (WSN) and the Internet of Things (IoT) to monitor the humidity and temperature of mushroom growing fields. They used a master-slave architecture, where each slave node from different growing fields sends temperature and humidity data to the master node, which is then updated in the Firebase database, from where the data can be accessed via smartphone. Although the experiments were conducted in a controlled environment, they still have an average error of 0.465°C and 2.67% in temperature and humidity control.

In the work reported in [18], the authors developed an embedded system to control humidity and temperature in growing oyster mushrooms in a small area as a test case. They have used an MCU ESP8266 module to control and monitor the growing field. They have used a standard IoT application called Cayenne to visualize the data. They have used an industrial application that has a monthly subscription fee and requires integration of the application and installation of the server, which is not very practical for the end user.

In the work mentioned in [9], the system for maintaining oyster mushroom cultivation with automatic temperature and humidity control was developed. The main components are Arduino Uno, relay, DHT11 sensor and Sprinkle. This system does not use internet to exchange data but uses LCD display. Since it is a physical display and there is no possibility of remote monitoring, it is not very practical to reduce labor and physical intervention in the cultivation process.

In the mentioned work [17], a system for monitoring and environmental control of indoor oyster mushroom cultivation was implemented using IoT. It uses an ATMega 2560 microcontroller as the motherboard, ThinkSpeak as the IoT platform via ESP8266-01 WiFi module and a LCD display to visualize the data. The sensors used for environmental data are DHT22 (humidity & temperature) and BH1750 (light sensor). The system is currently not suitable for control over the internet due to the quality of the internet. Data security is also an issue found in this study.

In the study conducted by the authors and reported in [3], the authors proposed a climate control system for mushroom cultivation. They used ESP -8266 and DHT22 modules to control and monitor the system. The authors tested their system for six days in a real mushroom growing center to control and monitor humidity and temperature. They provided a web application to monitor the real-time data and a physical display unit in the growing room.

From the works reviewed above, it can be seen that all related work on IoT-based mushroom cultivation done by [3, 9, 17, 18, 21] described the development of an intelligent system for monitoring the indoor environment of a mushroom cultivation. However, only the work of [3] tested the system in a real mushroom farm, others used a simulation model. Moreover, all of them worked on two parameters namely humidity and temperature except the work described in [17].

3 METHODOLOGY

The oyster mushroom cultivation monitoring and climate management system proposed in this study is created using a combination of IoT capabilities and automation system algorithms and cloud-based network accessibility. The technology was developed to reduce the response of the plant using sensors. This system uses a virtual server namely XAMPP [8] to run the connectivity between the sensors and the data generated by the sensors for the user interface of the system and a JSON [10] based request-response structure. The PHP programming language is used as server-side scripting to manage server-side requests and responses. As a prototype, the ESP 8266 module is configured with a single API gateway and a POST request for proof of concept. The operational flow of the proposed system is presented in figure 1.

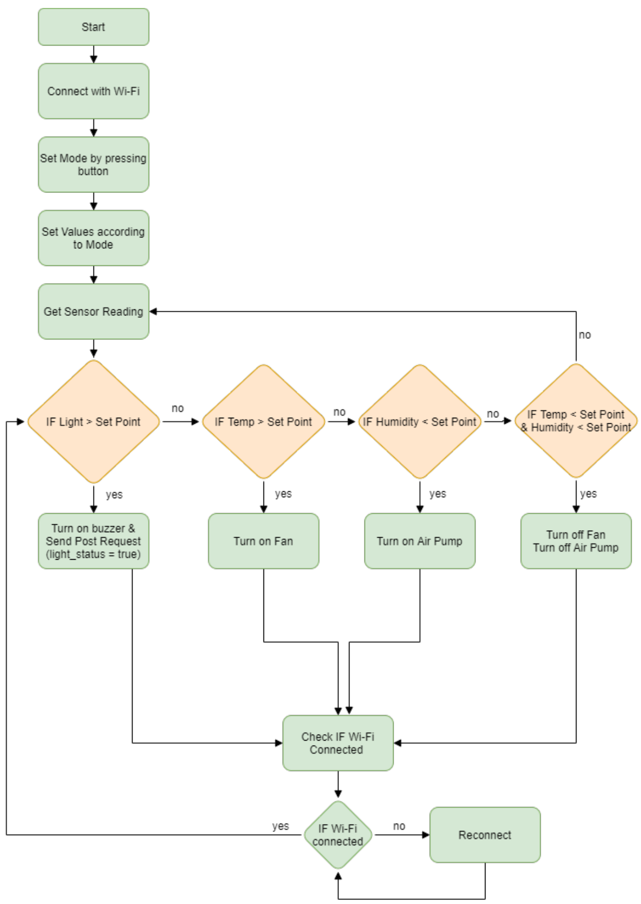

Figure 1: Overview of the proposed system, represented in flowchart.

While designing the hardware implementation of the proposed system, scalability of the system is the primary concern. We designed our system to be as small as possible for testing purposes. Nevertheless, any consumer can increase the coverage of the system by simply adding more sensors and maintaining the ratio and power of cooling fan and air pump . The internet connection of the hardware device with the virtual server is demonstrated. All the json data can be easily transferred from the hardware system to the server side and get the responses from the server. From this we can conclude that any standard IoT application built on any platform can be used with this framework. We used a prototype and tested the whole project in a 362.25 cubic inch plastic box (11.5 inch, 7.0 inch and 4.5 inch) . The temperature-humidity sensor (DHT11) was installed inside the box and transmits the temperature-humidity values to its own controller. A light sensor inside the box monitors the light intensity and sends a status value to the controller. Table 2 lists all the hardwares utilized in the proposed system with exact model numbers.

Table 2: Component specifications of the proposed system.

No	Component	Model
1	Controller	ESP-8266 Wi-Fi module
2	Humidity and temperature sensor	DHT11
3	Light sensor	GY-30
4	Air Pump	SB-248A
5	Fan	12V Cooling Fan
6	Breadboard	Mini
7	Led light	Red Led
8	Resistor	1k Ohm
9	Button	Miniature 2-PIN Single Pull Single Throw switch
10	Buzzer	High-pitch beep
11	Relay	5V DC,250V AC
12	Battery Holder	AA,4S
13	Jumper Cables	Male to Male Male to Female
14	Plastic Box	(Prototype Surface)

On the top of the box, the switch and buzzer are placed to identify the mode change with bright light alarm. The resistor connects the button to the controller which is used to switch the mushroom mode. For this button prototype, we use oyster mushrooms, a standard ideal oyster mushroom mode with three other modes: yellow oyster, tree oyster, and Indian oyster mushrooms. In total, there are four ways to change the mushroom mode. Here two relays of 5V DC 250V AC (10A) are used. The 1st relay controls the AC connection for the air pump and the 2nd relay uses the power of 4 AA batteries of 1.5V DC for the DC cooling fan. We used ESP -8266 as the central controller; here all the input parameters are received and processed for automation. ESP -8266 monitors the environment with its sensors and can control the ambient temperature and humidity with its relay if required. Also focused on IoT for testing only. When the ESP -8266 is powered on, it automatically connects to the nearest WiFi network. The IoT function is only active when the light intensity is high. The device sends a "POST" request to the server to inform the user about the light status.

Figure 2 shows the path design of the proposed system we used to build the hardware part. In the diagram, it can be seen that there are two relays that control the power supply to the fan of the air pump. In this system, the air pump is powered by AC. So we need to connect one of our relays to the primary AC power line. For this reason, we built an adapter (Figure 3) to make our AC power connection more portable.

At the system level, after we put together our project, the final result can be seen in Figure 4. In this system "ESP -8266 wifi module" is used as controller. "Arduino 1.8.13" is used as IDE for programming our system in "C" programming language. To make the ESM

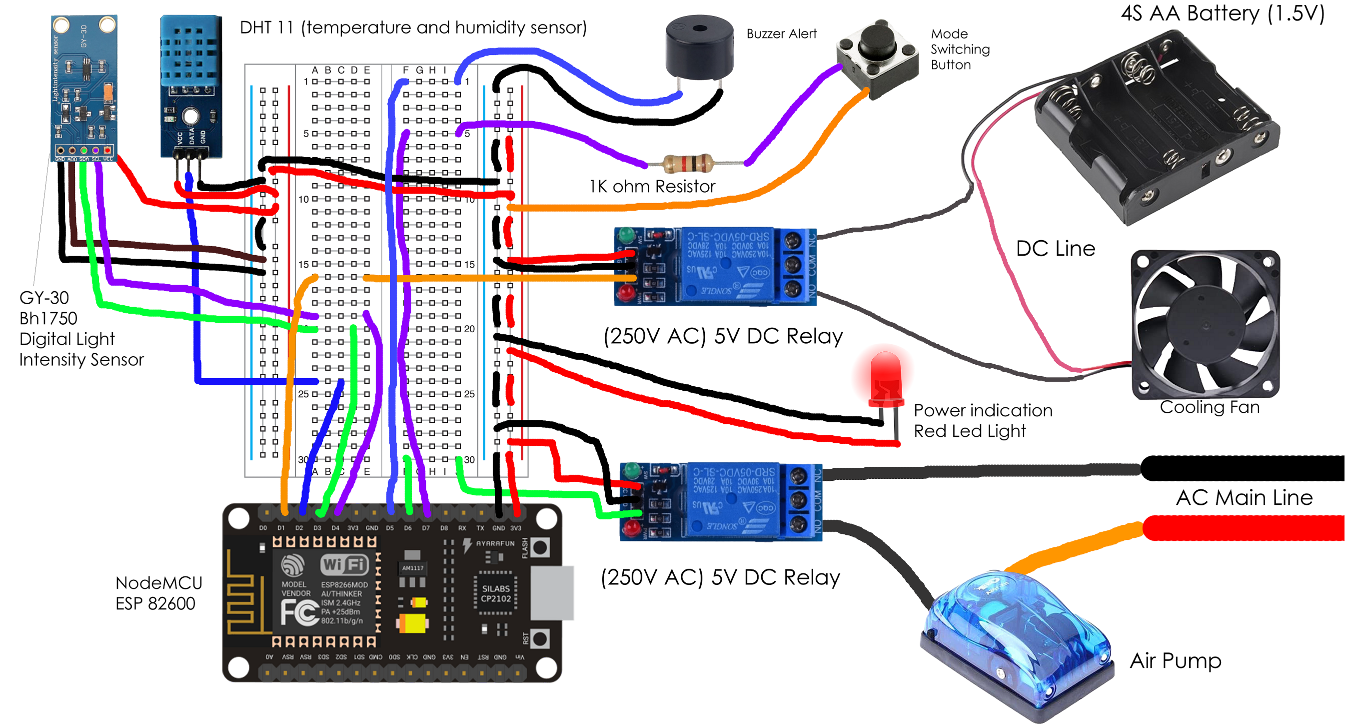

Figure 2: Path Diagram of Mushroom Cultivation Automation IoT System.

Figure 3: Portable AC power connector Relay as Adapter.

Figure 4: Total system after hardware assembly.

module work, a package called "ESP8266 Community Version 2.5. by esp8266" is installed in the "Board Manager" of the IDE. After the installation, "NodeMCU0.9" is selected from the "Tool/Board" section. Then upload speed is set to 115200 and CPU frequency is set to 80MHz. Then the module is connected to the computer and upload our code into the controller. Before uploading the code to the ESP module, all hardware parts need to be setup by following the path diagram presented in figure 2. Besides the default software libraries found in the IDE, some additional libraries are also used to make the sensors functional and readable. List of all the additional software libraries is provided below.

- BH1750 (V 1.1.4) by Christopher Laws [Light]
- SimpleDHT (V 1.0.12) by Winlin
- Adafruit Unified Sensor (V 1.0.2) by Adafruit
- DHT Sensor Library (V 1.3.10) by Adafruit

To setup the web application, the server side script is hosted in a computer using the XAMPP webserver [25]. After the hosting, the XAMPP control panel is started to run the apache webserver and then the web application interface is live within a local network to be accessed by the IoT devices and the user of the system. After configuring server side web application, the system is tested using client side testing tool postman [19]. All the codes and implementation details can be found in the following public github repository. Link to codes and implementation details github repository.

4 RESULTS AND DISCUSSION

This system is tested in Dhaka, Bangladesh, where annual average humidity is 65.8% [6] and during testing period the outdoor temperature was 33°C. Our Environment Control System was tested at indoor environment. We were successful to keep our environment in a mushroom friendly stage. The data sheet of that test is given below.

Table 3: Environment Control System experimental results

Serial	Time	Humidity	Temperature	Lux
1	1 sec	85.00%	29.70°C	5.83 lx
2	6 sec	81.00%	29.70°C	5.83 lx
3	16 sec	80.00%	29.80°C	5.83 lx
4	136 sec	80.00%	29.90°C	514.17 lx
5	154 sec	80.00%	29.90°C	507.50 lx
6	212 sec	79.00%	30.20°C	5.83 lx
7	221 sec	80.00%	29.90°C	5.83 lx

Table 4: Ideal Environment Values of Oyster Mushroom.

Parameter	Range	Unit	Controlled Equipment
Temperature	26-29	°C	Fan
Light	50-300	lux	Buzz Alert & WiFi Module API Call
Humidity	80-90	% RH	Air Pump as Custom Humidifier

From the test result, we can see the frequent update and control capability of our system. From the table 3, it can be seen that there is only a small time difference between level 1 and level 7. Nevertheless, the environment control system can maintain its target values at a minimum ratio within this short time span. This system can also control and maintain the environment of the incubation area at an ideal ratio for oyster mushrooms, as indicated in the table 4, while the outdoor temperature was 33°C and the humidity (average) was 65.8% during the test period.

In the table 3 the humidity value for Serial 1 is 85.00%, whereas our system brought the value to 80.00% within 16 seconds time difference (Serial 3) and the temperature is always kept at 29.70 - 29.80 in the best case.

From Serial 4-5, an additional 100W bulb was brought into the system environment to provide heat & high light intensity to verify risk management. In these steps, the system automatically sends an API request for light intensive alarm notification and at the same time the buzzer rang for alarm notification. There we can also see that within 9 seconds time difference at Serial 7 the environment was brought back to its ideal condition.

All [3, 9, 17, 18, 21] works are based on two main parameters (humidity and temperature). However, the hardware requirements are higher than our proposal. For the system described in [9], the hardware requirements are lower than our proposal. But this design had to compromise on the IoT function and light sensing. As a result, the design became more static. In most related work, the display was only used to show data. Our design provides the ability to select multiple mushroom types with a single button and buzzer. We managed all our operations with a single MCU ESP8266. Its built-in WiFi module can be used to transmit the sensor variables in the IoT. On the other hand, using an air pump and a "Stone Head Pump Air Filter" is a smart solution as a cheap alternative to an atomizer/ fogger. The comparison with [18] and the other related works shows that our proposed system is much more cost friendly, efficient and accurate compared to all other works proposed in [3, 9, 17, 18, 21] studies.

The most important thing is that all the above works are specifically designed for large-scale or urban agriculture. But our design can be a good example of portability. Because this 362.25 cubic inch system can keep itself dry even after hours of dealing with high humidity. Not a single water leak was detected during testing. And a single connection of the AC power line and only a single DC connection (3.3V) can keep the whole system running in automatic mode for an entire day.

So in the era of urban and densely populated society, our design proposal can be a timely solution. In the hectic life of city dwellers, setting up such an automatic IoT system can provide extra income for one’s family and extra food for others.

5 CONCLUSION

The IoT based mushroom cultivation monitoring and control system was successfully built using ESP -8266 wifi module controller and DHT11 humidity and temperature sensor. Temperature, humidity and light level are among the data collected with our programmed ESP -8266. The programme and how the system works are explained. If this system can be used at the production level, it has the potential to be a promising technology for mushroom production. The whole framework has been built on a low-cost open source platform to minimise the cost. However, only three important parameters are monitored and controlled in this system namely humidity, temperature and light. However, there are possibilities to integrate other parameters into the system. Integrating more parameters into the system and testing the system for controlling and monitoring mushroom cultivation can be the future scope of this work.

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