Design and Implementation of SENSEPACK: An IoT Based Mushroom Cultivation Monitoring System

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***Abstract*—In this paper, the design and implementation of SENSEPACK - a smart system to monitor room environment of mushroom cultivation farm is reported. The system measures the temperature, humidity, light and CO_2 level with appropriate sensors. The obtained data can be utilized to control the environment of the nursing room with the help of external devices such as water pump, exhaust fan, light bulb and air conditioner. An android/web-based application has been developed for the ease of monitoring the system. The software application allows automation and remote operation of the external devices to maintain and control the optimum environment.**

Keywords— Mushroom, Cultivation, Android, Arduino, Smart, IoT, Monitoring System

I. Introduction

Mushroom is an edible fungus which is cultivated using seeds developed from tissue culture technique. Mushroom is cultivated methodically in a clean environment without applying any chemical fertilizer and pesticides. To meet the high demand of mushroom because of its taste and nutrition, it is now cultivated over hundred countries [1]. Of these countries, China is producing over 70% of the total edible mushrooms produced in the world [1-2].

Mushroom cultivation can be divided into five phases. They are commonly termed as composting, spawning, casing, pinning and harvesting [1]. A very important material for mushroom cultivation is compost which is prepared from a combination of ingredients that includes horse manure and straw mixed with water. After preparation, the compost is mixed with spawn which produces mycelium (mushroom). The mycelium is then allowed to spread through the compost. After two-three weeks, the mycelium protrudes the compost. At this point the compost is spread in a bed where mushrooms grow. The beds should be placed in darks rooms where temperature needs to be around 23 degree Celsius and the humidity needs to be in between 70% and 80%. Therefore, it is necessary to include water spraying system. The optimum temperature for mushroom cultivation is 22 to 26 degree Celsius [3]. However, it has been reported that, low temperature and low humidity produce smaller mushrooms in large scale whereas high temperature and humidity produce larges mushroom on a small scale [3]. In final stage, the temperature is maintained to harvest the mushroom. Moreover, the temperature can be varied from 17 to 23 degree Celsius to cultivate mushroom throughout the year.

Mushroom cultivation, although free from chemical fertilizer and pesticides, is critical since it requires careful inspection and control of nursery environment. The temperature and humidity are two key factors for growth and development of different types of mushroom. Other important factors are the light intensity and air quality which also determine the amount of the production. Generally, these factors are controlled manually by farmers. Maintaining the optimum environment for mushroom cultivation manually is time consuming and challenging.

Automation and inclusion of smart electronic devices in mushroom cultivation have been on the rise in recent years [4-6]. This is mainly because of automated mushroom cultivation system reportedly being more efficient in controlling the optimum parameters and thus resulting in more yield [4-7]. In Thailand, Kaewwiset *et.al.* developed a fuzzy logic-based method to control temperature and humidity for three different mushrooms [4]. In 2018, a research group based in Indonesia controlled the same parameters by developing an Arduino based system [5]. They used an android app to monitor and control temperature and humidity by systematically turning on and off the heater and water pump. Mohammad *et. al.* developed an oyster mushroom cultivation system based on Internet of Things (IoT) in Malaysia in 2018 [6]. Adhitya *et. al.* compared fuzzy logic and neural network based mushroom cultivation system and determined the optimum and effective method [7]. Although neighboring countries are adopting technology-oriented systems for effective and efficient mushroom cultivation, Bangladesh is still struggling with the traditional method. Thus, despite having a suitable climate for mushroom cultivation, the annual production of mushroom

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in Bangladesh is still very low. Therefore, an automated monitoring and cultivation system is necessary to improve the production and commercialization of mushroom.

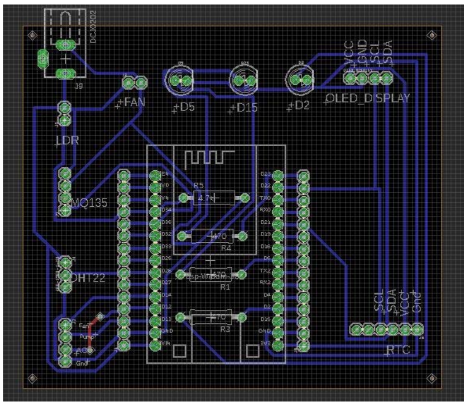
In this paper, the design and implementation of an IoT based mushroom cultivation monitoring system 'SENSEPACK' is reported which is developed by DataSoft, a leading (CMMI DEV/5, ISO certified) software product and services company in Bangladesh. The optimal IoT based solution takes inputs from the mushroom nursing environment using light sensor, gas sensor, humidity sensor and temperature sensor. It displays the sensed values to its user for remote monitoring. Using the device, it is also possible to control the optimum level of temperature, humidity, light intensity and CO_2 level in the room by turning on/off external devices such as exhaust fan, light bulb, AC and water sprayer. A dedicated application especially developed for the system allows to easily monitor and control in the environment in the nursing room. The application allows controlling the optimum environment both manually and automatically for four different mushroom species namely, oyster, milky, button and shitake mushroom. The system is designed to help a mushroom cultivator as an assistant to cultivate mushroom and pave the way for efficient and highly yielding indoor gardening. Using the proposed solution, it will also be possible to produce mushroom efficiently throughout the year.

II. METHODOLOGY

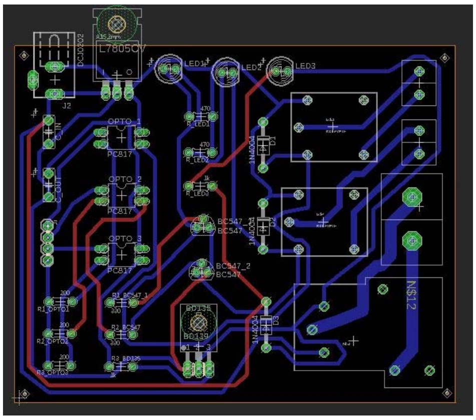
The methodology of this work has been divided into two parts. The first part is the design and hardware construction of the monitoring system. The second part is the development of the graphical user interface (GUI) for monitoring and controlling the system.

A. *Hardware Design and Implementation*

The IoT based mushroom cultivation system has been designed with an Arduino Mega microcontroller and an ESP12E Devkit being at the core of its components. The two separate designs have been carried out for sensor system and control system. The first task of the system is to take inputs from the environment by sensing where it has been installed. For temperature and humidity sensing, a low-cost digital sensor DHT 22 has been used. For CO_2 gas sensing, MQ – 135 has been used. These two sensors along with light dependent resistors (LDR) have been connected to ESP12E Devkit. The system takes inputs from these sensors and logs the data for remote monitoring and controlling. To control the room environment, there is a provision to connect four external devices to the microcontroller board. An air conditioner, an exhaust fan, a water pump motor and light bulb can be used to control temperature, CO_2 level, humidity and light intensity of the nursing room respectively. The interfacing of these devices has been carried out in a separate board. The PCB layouts of the sensor board and control board are shown in Fig. 1(a) and 1(b). The schematic of the sensor board can be seen in Fig. 2.



(a)



(b)

Fig. 1. PCB layout for (a) sensor board (b) control board

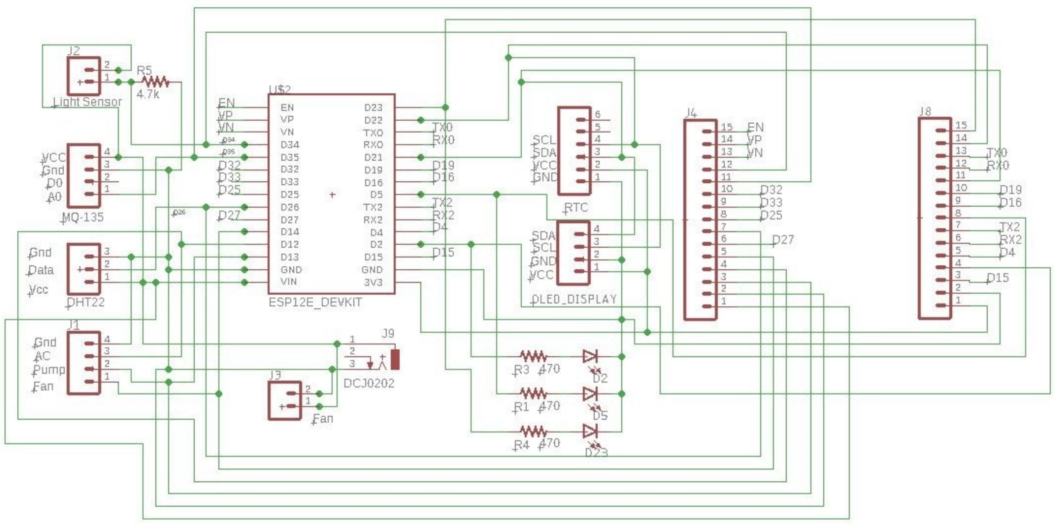


Fig. 2. Schematic of the sensor board.

The control board has been designed for controlling different external devices (AC, water pump motor, exhaust fan, light bulbs). The devices have been connected with the Devkit using standard 220V to 5V relay circuit. Table I lists the components that have been used for construction of the system.

TABLE I. COMPONENTS USED IN SENSOR BOARD AND CONTROL BOARD

Serial No.	Name	Remarks
1	DHT 22	Temperature and Humidity Sensor
2	MQ- 135	Gas sensor
3	LDR	Light Sensor
4	Arduino Mega	Microcontroller
5	ESP12E Devkit	UART WiFi Module
6	DCJ0202	DC power connectors
7	BC 547	Transistors
8	Relay	220 V to 5 V
9	Display	OLED
10	DS1307	Real time clock
11	BC 547	NPN transistor
12	BD 135	NPN transistor
13	1N4004	Diode
14	L7805	DC voltage regulator
15	Resistors	Circuitry
16	LED	On board status indicators

B. *Graphical User Interface*

The automated mushroom cultivation management system has been integrated with IoT for remote monitoring and controlling. An android based application has been developed to control the room environment remotely from anywhere anytime. This IoT solution lessens manual labour to substantial extent. The android app along with the device is the integrated IoT based solution.

After installing the app on their mobile device, a user can log in to the app using valid username and password (Fig. 3(a)). After login, the user can see all the sensors data from the monitoring system (Fig. 3(b)). In addition to monitoring, the application allows to automatically maintain the optimum environmental for mushroom cultivation. A user can also manually control the components of the system. As it can be seen in Fig. 3(c)-(d), a user can set optimum temperature to control the cultivation house environment through given cooling system in the mobile app. To enable water spraying system user can set time for water spraying in several times (maximum 5 times) per day as depicted in Fig. 3(e). In those selected times device starts processing automatically to create mist from water with the system installed in the nursing room. It can also be seen in Fig. 3(f) that there are two buttons in the app to operate exhaust fan and water pump. By using this feature, the user can switch them on/off manually at anytime from anywhere. The monitoring and controlling can also be performed using a browser-based user interface.

The mobile app or browser-based monitoring system is connected to the sensor and control boards using web server and cloud computing technology thorough the internet. The complete workflow incorporating the hardware design and software-based monitoring system is shown in Fig. 4.

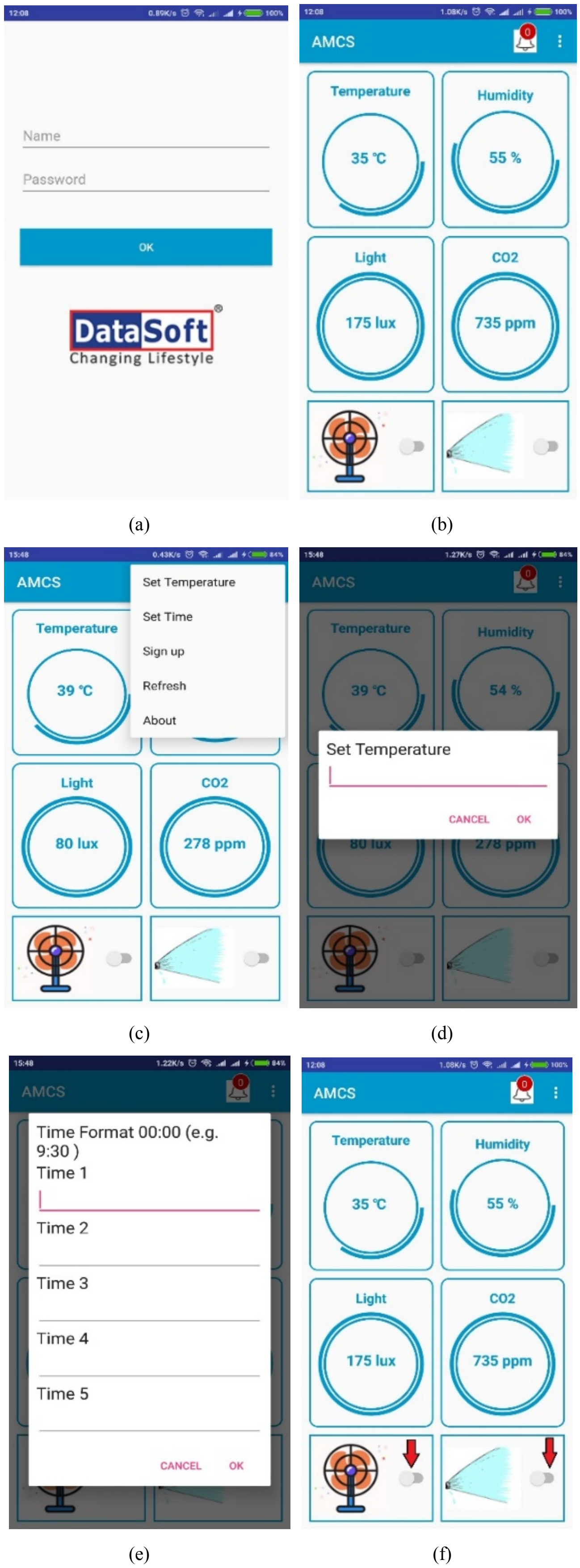


Fig. 3. Pictorial description of the monitoring system (Android app) developed for the device. (a) Log in (b) Data monitoring (c) Optimum value setting (d) temperature setting (e) Time setting (f) External device controlling.

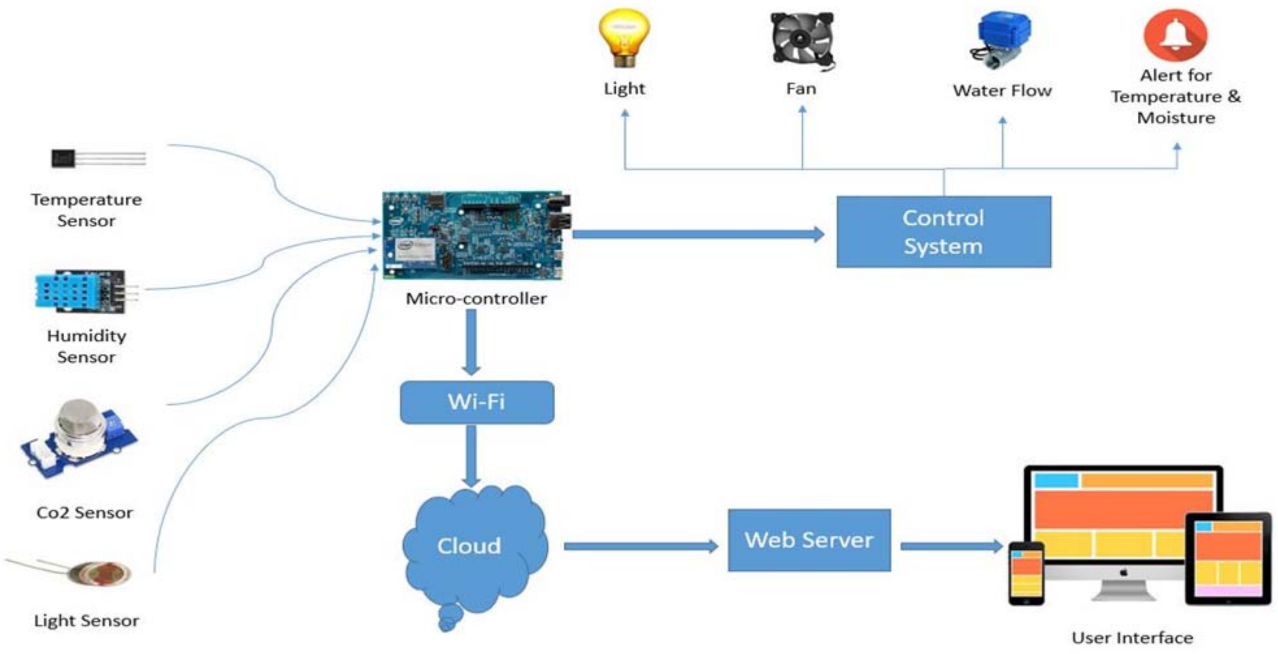


Fig. 4. Flow diagram of the proposed mehtodology

III. Results and Discussions

To monitor performance, the system has been installed in two mushroom cultivation rooms of National Mushroom Development and Extension Center (NMDEC) in Savar, Bangladesh. In each room, temperature and humidity sensors, gas sensor and light sensors are placed to collect data for monitoring purpose. The water spraying system, exhaust fan, light bulbs and AC are also installed and connected to the monitoring system to control the environment in the rooms. In this section, the performance of the monitoring system has been discussed.

Fig. 5 shows the plot of humidity of one nursing room of NMDEC in one day. The humidity of the room has been initially recorded at around 50%. Then the water pump motor has been remotely turned on for a short period at five different times starting from 10.00 AM morning to 06.00 AM morning the next day.

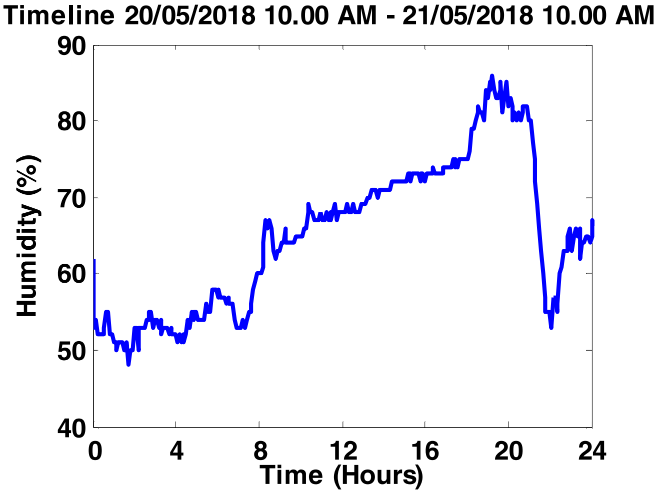


Fig. 5. Monitored values of humidity in one day.

It can be seen in Fig. 5 that the humidity of the room gradually increases with time as recorded by the monitoring system. It has been possible to monitor the humidity from 50% up to 85% in one day. The optimum humidity for oyster mushroom is 60-65%, 70-80% and above 85% for mycelium growth, fruiting bodies growth and post fermentation respectively [3]. With the proposed system, it is be possible to monitor all range of humidity efficiently. It is also possible to control the humidity of the ambient using the water spraying system, which is beyond the scope of this work.

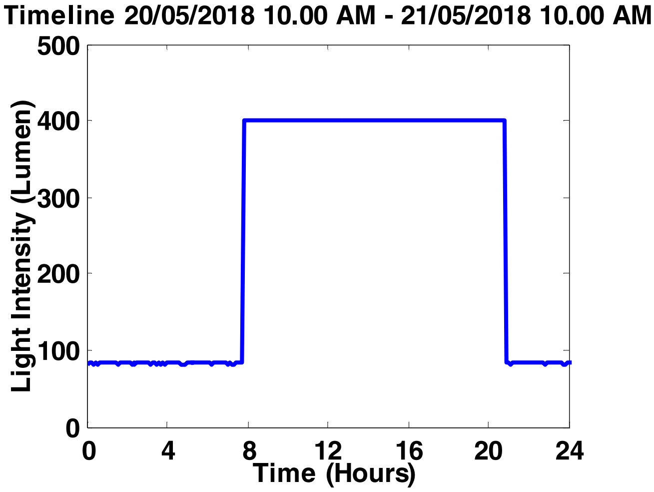


Fig. 6. Monitored values of light intensity in one day.

The light intensity inside the room has also been monitored along with the humidity. The monitored data has been plotted with respect to time (one day in the same room) and shown in Fig. 6. The light bulbs installed in the room were set to turn on at 06.00 PM evening and turn off at 06.00 AM next morning. It can be seen in Fig. 6 that the light intensity is 80 Lumen when the light bulbs are not turned on and 400 Lumen during the time when the light bulbs are turned on.

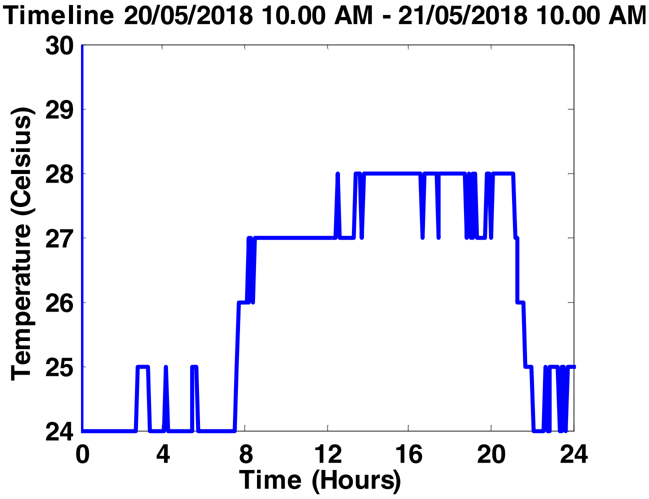


Fig. 7. Monitored values of temperature in one day.

Fig. 7 shows plot of monitored data of temperature in one day scale for the same room as of Fig. 5. It is notable that the temperature remains relatively constant at 24 degree Celsius in first eight hours i.e. from 10.00 AM morning to 06.00 PM evening. However, after 06.00 PM, a gradual increase in temperature has been recorded by the system. This is because of the light bulbs installed in the room being turned on from 06.00 PM to 06.00 AM next morning, as mentioned earlier. In this time, temperature has been monitored and maximum temperature noted is 28 degree Celsius. The temperature decreased to 24 degree Celsius the next morning starting from 06.00 AM. The suitable temperature for growth of oyster mushroom is 22-26 degree Celsius [3] [8].

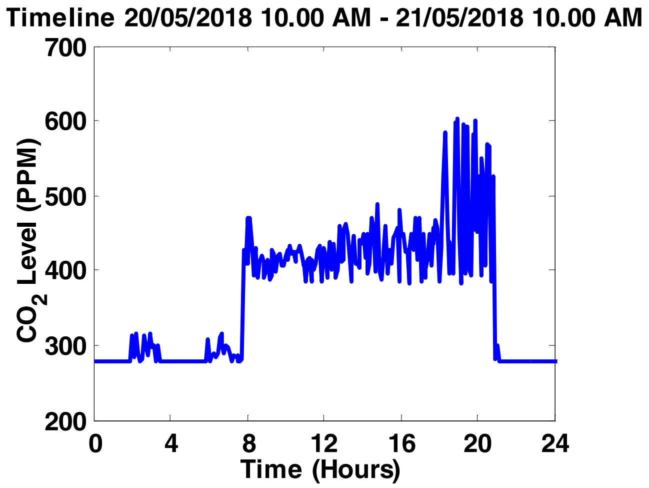


Fig. 8. Monitored values of CO_2 level in one day.

Fig. 8 depicts the monitored data of CO_2 level measured in PPM (parts per million) and plotted against time. Patterns similar to light intensity and temperature have been observed in the level of CO_2. This can be attributed to the fact that in presence of artificial light, the mushroom tends to generate more CO_2 than in the usual state. From 06.00 PM to 06.00 AM, CO_2 generation is higher with peak value reaching around 600 PPM in midnight.

The relationship between temperature and light intensity has been further monitored on a four-day timeline. The monitored data have been depicted in Fig. 9 and Fig. 10. Here the light bulbs have been turned on for longer period and as expected, the temperature increase has been noted higher than before. The maximum temperature noted in this case is 32 degree Celsius.

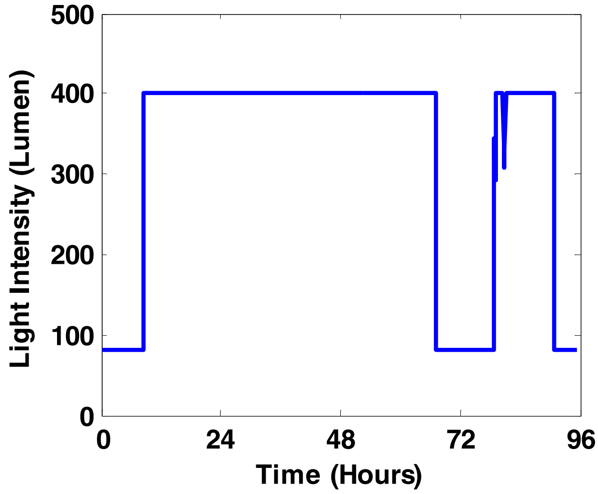


Fig. 9. Monitored values of light intensity in four days.

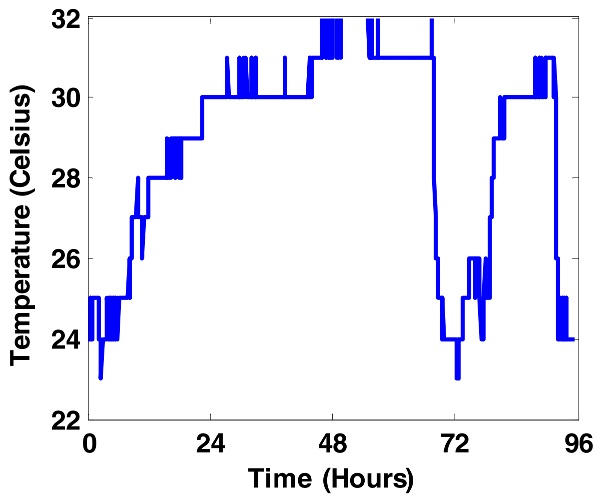


Fig. 10. Monitored values of temperature in four days.

Monitoring the related parameters is the first outcome of the IoT based mushroom cultivation system. The second stage will of course be controlling the parameters using the external devices installed along with the system in the nursing room. Currently, the system allows its user to maintain certain levels of CO_2 level and humidity through remote controlled operations on water pump and exhaust fan. Controlling temperature and light intensity will be added to the integrated system once permitted by NMDEC. This will be discussed in the future scopes.

IV. Conclusions

In this paper, the design and implementation of an IoT based mushroom cultivation monitoring system is presented. In the study, temperature, humidity, light intensity and CO_2 level, which are critical parameters for mushroom growth and production, have been monitored for different mushrooms. The system allows to automatically optimize these parameters by analyzing the collected data. It is also possible to control the parameters with the help from external devices connected to the monitoring system. The whole process can be done remotely by an IoT based application. If implemented, this solution has the potential to remarkably improve the production of mushroom at reduced cost and labour.

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