AN INTERFACE CIRCUIT FOR AGRICULTURE SENSOR

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UNIVERSITI SAINS MALAYSIA

2017

AN INTERFACE CIRCUIT FOR AGRICULTURE SENSOR

by

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Thesis submitted in partial fulfillment of the requirements

for the degree of

Bachelor of Engineering (Electronic Engineering)

JUNE 2017

ACKNOWLEDGEMENTS

I would first like to express my deepest gratitude to Assc. Prof. Ir. Dr. Arjuna Marzuki, my final year project supervisor and thesis advisor, for his guidance and support which ultimately helped in the completion of this project. His guidance and patience in the process of the development of project are much appreciated. The support from him for the involvement of this project in the SIRIM Invention, Innovation & Technology Expo (Si2TE) 2017 were also invaluable to me. His care and support for me has led me to success and I would like to give him a million thanks.

A special thanks to the local farmers in Malaysia, who have aided me by providing insightful information and a load full of advices. Thanks to Mr. Ong of local mushroom farm in Batu Lanchang for providing invaluable information and advice for the development of this project. He also provided the venue for my experiments to be carried out.

Last but not least, I would like to give an appreciation for the supports from my beloved family and friends during the project. This accomplishment would not have been possible without them. Thank you.

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LIST OF ABBREVIATIONS

API	Application program interface
CSV	Comma-separated Values
GSM	Global System for Mobile communication
GUI	Graphical User Interface
HTTP	HyperText Transfer Protocol
IoT	Internet of Things
ISM	The Industrial, Scientific and Medical radio bands
LCD	Liquid Crystal Display
LDR	Light Dependent Resistor
LED	Light Emitting Diode
ppm	parts per million
RH	Relative Humidity
SD	Secure Data
SMS	Short Message Service

LITAR ANTARAMUKA SENSOR PERTANIAN

ABSTRAK

Sensor memainkan peranan yang penting dalam pertanian moden. Pengunaan sensor dalam pelbagai sektor pertanian mengurangkan kejejasan cuaca dan persekitaran terhadap tanaman, meningkatkan hasil dan mengurangkan kos operasi. Industri cendawan merupakan sebuah industri yang baharu dan kecil berbanding dengan industri pertanian yang lain di Malaysia. Daya pengeluaran cendawan di Malaysia tidak mampu memenuhi permintaan pasaran. Pengimportan cendawan semakin meningkat setiap tahun dan jumlahnya telah mencapai 10 juta tan pada 2012. Oleh sebab kebanyakan ladang cendawan di Malaysia adalah secara kecil-kecilan, daya pengeluaran ladang-ladang tersebut telah dihadkan oleh sistem kawalan yang kurang sesuai dan kekurangan sumber kewangan. Projek ini membentangkan sebuah litar antaramuka sensor pertanian bagi memantau dan mengawal keadaan persekitaran dalam sebuah ladang cendawan. Projek ini dibina menggunakan sebuah sensor suhu dan kelembapan, sebuah sensor karbon dioksida, sebuah perintang peka cahaya, sebuah papan mikrokontroler Arduino Uno, dan sebuah modul Wi-Fi. Sistem ini mampu mendapatkan data daripada sensor yang diletakkan di ladang cendawan dan meghantar data tersebut ke awan 'ThingSpeak' untuk penyimpanan. Data tersebut boleh diakses oleh pengguna melalui 'ThingSpeak'. Arduino Uno digunakan untuk proses data yang didapati, lalu mengawal peralatan-peralatan di ladang cendawan seperti pelembap udara, kipas dan lampu untuk mengekalkan persekitaran yang optimum untuk pertumbuhan cendawan. Suhu, kelembapan, kepekatan karbon diosida dan keamatan cahaya yang diukur oleh sistem ini mempunyai peratusan ralat serendah masing-masing 0.4%, 1.5%, 2.2% and 1.34%.

AN INTERFACE CIRCUIT FOR AGRICULTURE SENSOR

ABSTRACT

Agriculture sensors play an important role in modern agriculture. The use of sensors in various agriculture sectors minimises the environmental impact on crops, helps in increasing yield and saving cost of operation. Among all agriculture industries in Malaysia, the mushroom industry is a comparatively new and small industry. The production of mushrooms in Malaysia is unable to meet the demand in local markets. Import of mushrooms has been increasing every year and the amount has reached 10 million tons of mushrooms in 2012. As most of the mushroom farms in Malaysia are small-scaled, their production capability is limited by inadequate environmental control system and the lack of financial resources to upgrade the systems. This project presents an agriculture sensor interface circuit to monitor and control the environmental conditions in a mushroom farm. It utilizes a temperature and humidity sensor, a carbon dioxide sensor and a light dependent resistor, the Arduino Uno microcontroller board, a Wi-Fi module. The system is able to acquire data from the sensors that are placed in the mushroom farm and send the data to ThingSpeak cloud for storage. The data can be accessed via ThingSpeak and an Android app designed alongside the project. Arduino Uno is used to process data acquired from the sensors and control the appliances such as humidifier, fan and light in the mushroom farm to regulate the environmental condition. The temperature, humidity, carbon dioxide and the light measured using the circuit developed have percentage error as low as 0.4%, 1.5%, 2.2% and 1.34% respectively.

CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture is an important sector of Malaysia's economy [1]. Back in the 1950s, agriculture contributed nearly 50% to the national gross domestic product (GDP) [2]. However, the contribution had declined to 9.7% in year 2008. The decline is due to several challenges. Some of the major challenges faced by agriculture sector in Malaysia are persistent poverty among rural farming community, food insecurity, labour intensive and high cost of land [3].

Among all agriculture products in Malaysia, mushroom is found to be a viable option to develop a more reliable income source, especially for small-scale farmers [4]. In fact, mushrooms are listed as one of the seven high-valued crops by Malaysian government [5]. Besides generating income, it can also improve food security by increasing diversity. This is because mushrooms have short growing time, requires limited land and low investment as the growing medium is widely available [4].

Mushrooms are rich in protein [6]. In fact, its protein value ranks just below animal meat and well above other foods, making it a perfect meat substitute for vegetarians [7]. It contains all nine essential amino acids required by human [8]. In addition, mushrooms also contain nutrients such as phosphorus, iron and vitamins. Besides having high nutritional value, mushrooms also have medicinal properties and have been made into dietary supplements [6, 8].

Mushroom industry is a comparatively new industry in Malaysia compared to other agricultural industry. However, this industry is growing steadily and its development has been intensified in Malaysia's agriculture transformation program [10]. Although Malaysia has the potential to be a large mushroom producer, there are still many challenges faced by this industry. One of the challenges is that the productivity of domestic production of mushrooms is low and is unable to meet the demand of the market. Thus, Malaysia has to import tons of mushrooms every year since 2009. The import has reached more than 10 million tons in 2012, driven by high local demand [10]. Besides, mushroom farming is very labor-intensive [11]. Thus, to expand the industry in Malaysia, an automatic system is needed to increase the yield of mushrooms with less labour.

The focus of this project is to develop an interface circuit for several agriculture sensors to aid mushroom agriculture. The interface circuit enables communication among the agriculture sensors, environmental control system, and a computer. Instead of using wired connection, the data acquired from the sensors is transmitted via Wi-Fi as large number of cables can be a big obstacle in a mushroom farm. A GUI (graphical user interface) is included to display the data from the sensors. The environmental control system can be controlled remotely by the user or automatically based on the data acquired. The control algorithm is developed using Arduino IDE.

1.2 Problem Statement

Mushroom farming is labor-intensive and requires precision. Without suitable environmental condition, mushrooms could hardly reproduce [12]. Timer-controlled humidifier used by most of the mushroom farmers in Malaysia is not consistent in maintaining the humidity and temperature in the mushroom farms, causing lower productivity. Thus, sensor-based environment control system is needed.

Mushroom farming is very labor-intensive, yet most of the mushroom farmers in Malaysia are small-scaled farmers with just a few workers or none at all which do not operate 24 hours [11]. Most of the time no one is at the mushroom farm. Thus, a remote monitoring system is needed to monitor the condition of the mushroom farm to prevent undesired conditions that might cause the death of mushrooms.

A timer-controlled humidifier is commonly used in mushroom farms in Malaysia. A timer-controlled system may cause excess moisture, which encourages certain contaminates [13].

In order to overcome the problems stated above, a system that can monitor and control the environmental condition remotely is required.

1.3 Research Objectives

- To design an interface circuit for agricultural sensors such as light sensor, carbon dioxide sensor and temperature and humidity sensor which can measure data with percentage error less than 5%.

- To design a remote monitoring system which includes a user interface to display data from the sensors.

- To develop a close-loop control system to maintain optimum growth environment for mushrooms by maintaining temperature at 20 to 25 degrees Celsius, humidity at 85%RH (Relative Humidity) or above, carbon dioxide concentration below 600ppm (parts per million) and light intensity above 500 lux for 12 hours.

1.4 Scope of Research

This project can be divided into two parts — monitoring system and environmental control system.

The first part is to develop a monitoring system to monitor the growth environment of mushrooms wirelessly. This includes building an interface circuit for data acquisition, transferring the data to a server using a Wi-Fi module and displaying the data via a user interface. A light sensor, a carbon dioxide sensor and a temperature and humidity sensor will be included in the circuit.

The second part is to build an environmental control system to maintain optimum temperature, humidity, carbon dioxide concentration and light intensity for mushroom growth. This includes analyzing the data acquired in the first part and developing a control algorithm to automate a misting system and a fan.

1.5 Thesis Organization

There are five chapters in this report.

Chapter 1 gives an overview of this project. The problem statement, objectives and scope of research are included in this chapter.

Chapter 2 features the literature review. Detailed background information and previous works are discussed and analyzed.

Chapter 3 discusses the methodology used in this study in order to develop an agriculture sensor. Descriptions and explanations of processes involved are included.

Chapter 4 shows the results of this study. The results and performance of the system are discussed.

Chapter 5 concludes the study and presented the possible improvement to be done for the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This part is to show detailed background information and to analyze previous works related to this topic.

Mushrooms are a type of fungus and they do not contain chlorophyll, unlike plants [14]. This means that their growing environment is different from plants. Different species of mushroom may require different environmental conditions, but generally, the conditions can be summarized into temperature, humidity, light and fresh air [12]. Air flow of the mushroom growing room is an important aspect of mushroom growing as directly affect the carbon dioxide content of the room [15].

Growth cycle of mushrooms can be simplified into two stages — the vegetative phase, which consists of mycelia expansion and maturation, and the reproductive phase [16]. To cultivate mushrooms, a mycelium culture is allowed to propagate on sterilized cereal grains, forming spawn. The spawn is inoculated into a sterilised substrate and the substate is allowed to incubate. During incubation, mycelium grows throughout the substate and uses up the nutrients in it. This process is called spawn run [13].

During spawn run, the optimum temperature is around 25 degree Celsius and high carbon dioxide concentration is favourable. After that, the mycelium reaches the reproductive stage and is capable of producing mushrooms. Key factors which induces the production of mushrooms are sudden decrease in temperature (decrease of 5 to 10 degree Celsius), and sudden decrease in carbon dioxide concentration [14].

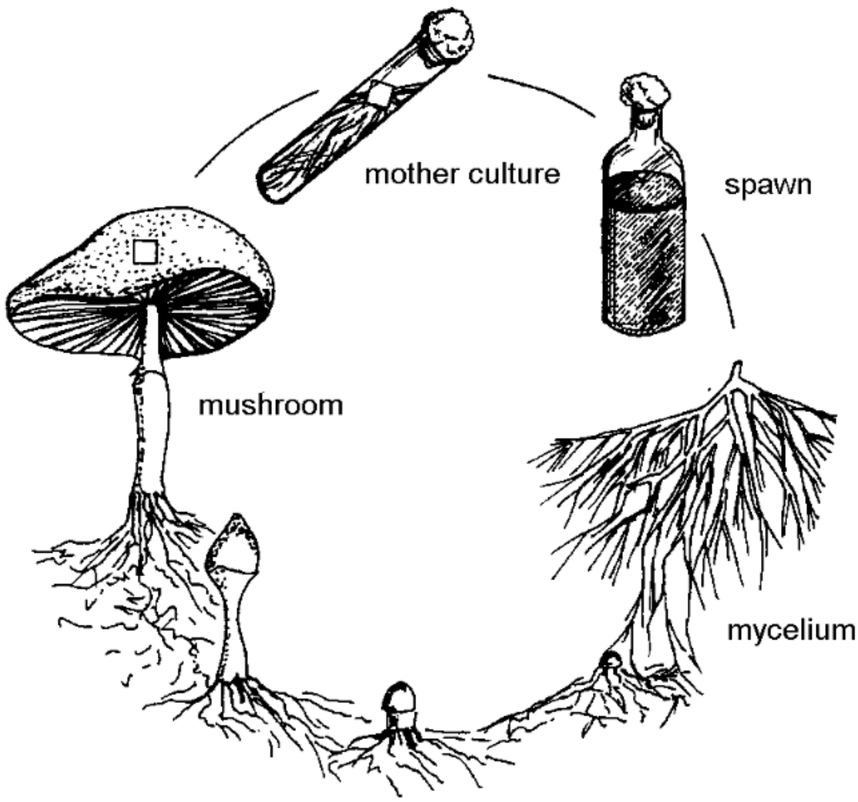

Figure 2.1: Mushroom Life Cycle [14].

Figure 2.1 shows how mushrooms are cultivated. Mycelium cultures are taken from a mushroom and propagated on sterilized cereal grains of other suitable substrates. The spawn is then used in mushroom cultivation. After pinhead initiation, the optimum temperature for growth is around 10 to 25 degree Celsius, 85% to 92 % relative humidity, carbon dioxide concentration less than 600ppm and 500lux to 2,000lux for 12 hours [12]. A study done by F. Vieira et al.[17] shows that mushrooms cultivated between 15-20 degree Celsius present better quality and durability than those cultivated at 25 degree Celsius. As different phases require different humidity, temperature, carbon dioxide and carbon dioxide concentration, a system with pre-set conditions for different phases could make it easier for mushroom farmers.

Mushrooms can be cultivated both outdoor and indoor. Indoor cultivation methods produce relatively higher yields as it allows precise environmental control, but are far more costly than outdoor cultivation methods [13]. The average temperature is too high and humidity is too low in Malaysia for outdoor cultivation method as Malaysia is a tropical country. Mushrooms could dry up easily under direct sunlight. Thus, indoor mushroom cultivation with controlled environment is encouraged [18].

Figure 2.2: Dried-up mushrooms due to low humidity.

2.2 Mushroom Agriculture in Malaysia

In Malaysia, production of mushroom is still low compare to its demand. Daily demand for fresh mushrooms is around 50,000kg in local market, while the supply is only 24,000kg. In addition, the number of mushroom farmers and companies in Peninsular Malaysia has decreased from 850 in year 2008 to 320 in year 2012 [5]. Technology that uses less labour is needed in mushroom agriculture to increase productivity.

Currently, a timer-controlled misting system is used to control the humidity in most of the small-scale mushroom farms in Malaysia. This method is not accurate as humidity in the air varies according to the weather. A timer-controlled system may cause excess moisture, which encourages certain contaminates [13]. An environment control system based on humidity sensors is needed to maintain optimum humidity. According to Encik Muhammad Arif, the president of myAgrosis Club in Universiti Sains Malaysia, although the humidifier in their mushroom farm is controlled by a commercial timer, frequent manual watering is still needed as the system is not reliable.

2.3 Sensor-based Monitoring and Control System

Modern agriculture depends strongly on sensors to provide accurate information such as crop, soil and environment conditions [19]. Sensor-based systems are effective in increasing yield and reducing cost [20]. Traditional data collection methods which require trips to field sites, data entry and surveys are time consuming compared to sensor-based systems, which can automate many of these processes and allow real-time monitoring.

Sensor-based systems require a series of interlinked components to carry out specific functions. The series of components include: 1) the sensor itself, which is used to measure the parameter(s) of interest; 2) a microcontroller that acts as the brain of the system, it controls how does the whole system function, how is the data process etc.; 3) a data logger and micro SD (secure data) card, which stored the data collected; 4) telemeters which allows wireless transmission of data and; 5) a power supply, for example, batteries [21].

A number of sensor-based systems have been proposed and in the past few years. One of them is done by X. Wang [22]. He developed a temperature and humidity monitoring system, using AT89S52 as the controller, SHT10 as temperature and humidity sensor and TC35i GSM (Global System for Mobile communication) Module for wireless communication. The system is able to detect temperature and humidity and display via a Nokia 3310 LCD (Liquid Crystal Display) module. When temperature or humidity exceeds the limit, the system will send short messages to mobile phones to alert the user.

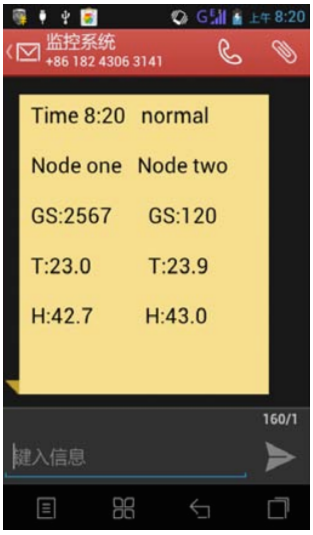

Figure 2.3: Short message alert sent to mobile phone of the user [22].

Another system which is done by A. Rahali [23] is also based on GSM. It is a greenhouse monitoring and control system. This system is more complicated compared to the system done by X. Wang [22], as it does not only allow data acquisition, it also allows user to control humidity, temperature and soil moisture via SMS (Short Message Service). The temperature sensor used is LM35DZ and the humidity sensor used is HIH-4000-001.

Realizing the importance of indoor environment quality, Yasen S. Kalinin et al. [24] had made some effort in the design and implementations of an indoor environmental monitoring system based on Arduino. Their system consists of a wireless module, a main module and dialer module. The dialer module will make a call when there is fire and send an SMS if two or more reading are out of acceptable range for more than 10 seconds. It also allows user to set four phone numbers which the dialer will call or send SMS to by sending a SMS to the dialer.

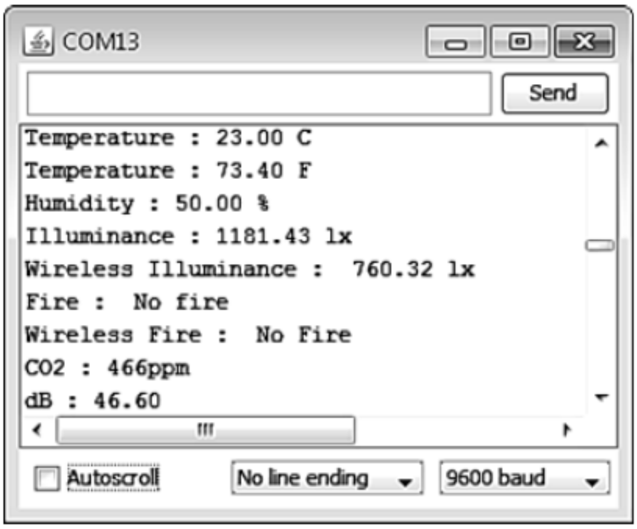

Figure 2.4: Serial Monitor of Indoor Environment Monitoring System by Yasen S. Kalinin et al. [24].

A more recent system is a a ZigBee-based energy efficient environmental monitoring alerting and controlling system proposed by K.Lokesh Krishna et al. [25]. The system consists of an ARM7 processor, various sensors and ZigBee module. Sensors gather various physical data such as temperature, humidity and soil moisture from the field and transmit it to the processor and to the end user via ZigBee communication.

2.4 Commercially Available Devices

There are a few sensor-based devices for environmental monitoring on control in the market. One of the devices is EVC-1, an environmental controller by Sentinel. It is designed to maintain temperature, humidity and carbon dioxide at a specific level. It controls temperature by controlling a device such as an air-conditioner or an exhaust fan. The device is compact and has all basic functions to maintain suitable environmental conditions for a small-scaled farm. However, this device does not allow monitoring of the conditions as it does not have any display and cannot be connected to a computer.

Figure 2.5: EVC-1 by Sentinel.

Another sensor-based device that is commercially available is the Winland EnviroAlert IP Monitoring Console [26]. This device is able to monitor up to four wired sensors and four wireless sensors. It has a wireless range is 300 meters between sensors and its base unit. Its features include data logging, alarm, a large LCD display and temperature and humidity Hi/Lo set points. Its sensing units are sold separately. The weaknesses of this system are high power consumption and has no environmental control capability [27].

Figure 2.6: Winland EnviroAlert IP Monitoring Console, EA800-ip [26].

2.5 Wireless Transmission of Data

Wireless transmission of data can be achieved using several technologies. Generally, there are four widely used technologies for wireless transmission with low power consumption — Bluetooth, UWB, ZigBee and Wi-Fi over ESP 8266. This section will discuss and compare these technologies.

Bluetooth devices operate at 2.4GHz in license-free ISM (The Industrial, Scientific and Medical radio bands) band, and has data rate of less than 3Mbps [28]. There are two connectivity topologies in Bluetooth — the piconet and scatternet. A piconet is a network that contains a Bluetooth device serving as a master and one or more Bluetooth devices serving as slaves. Slaves can only perform point-to-point communication with their master, while the master can perform either point-to-point or point-to-multipoint communication. A scatternet is a network consisting of two or more piconet(s) [29]. Bluetooth devices have low power mode and are highly integrated. However, they are only suitable for short distance transmission as its range is only about 10m [30]. The first application of wireless sensor network in a agriculture is developed using Bluetooth. It is a monitoring and control system [31]. Figure 2.7 below shows a Bluetooth Scatternet which consists of one or more Piconets.

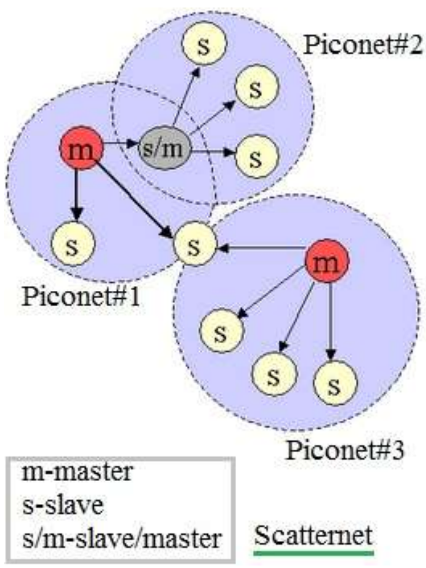

Figure 2.7: Bluetooth Scatternet [32].

The Ultra Wideband (UWB) technology is a high-speed wireless communication that occupies at least 25% of its center frequency. As its name implies, UWB has a very large bandwidth that can go up to 480Mbps. This is a huge leap from the 1Mbps of Bluetooth [33]. The range of frequencies of UWB is from 3.1 to 10.6GHz. Despite having wide bandwidth and relatively low power consumption, UWB is limited to short distance transmission [29]. An detailed study had been done on the implication of UWB on wireless sensing network [34]. The study proposed that UWB is a good candidate for high data rate transmission.

ZigBee is designed for implementing low-cost, low-data-rate, short-range wireless networks with extended battery life. ZigBee-based devices operate in 868MHz, 915MHz and 2.4GHz frequency bands with a maximum data rate of 250Kbps. Despite having the longest battery life as compared to Bluetooth and UWB, Zigbee has the lowest data rate among the three technologies. It is not suitable to be used when wireless Internet connection that requires higher data rate is required [28]. An effort in applying the ZigBee technology in carrying in carrying out monitoring operations was carried out by Prof C.H. Chavan et al. [35]. It is a wireless monitoring system that monitors soil moisture, temperature and humidity for agriculture use.

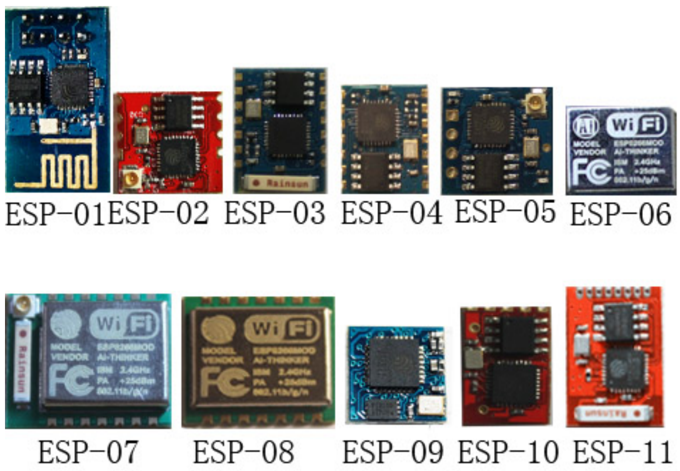

Figure 2.8: ESP8266 Wi-Fi module variants [36].

ESP 8266 is a low-cost System on Chip Wi-Fi to serial module. It is used to develop systems with embedded Wi-Fi capabilities. The module has various variants, ranging from ESP 8266 01 to ESP 8266 13 with increasing features and capabilities [37]. It operates in three different modes to optimize energy usage: active mode, sleep mode and deep sleep mode. ESP 8266 module can be used to implement Internet of Things. Information collected from sensors can be directly transmitted to a server to be monitored. Table 2.1 shows the current ratings in various modes of ESP 8266 series.

Table 2.1: Current Ratings in Various Modes of ESP 8266 series [37].

Mode	Typ	Unit
Transmit 802.11b, CCK 1Mbps, POUT=+19.5dBm	215	mA
Receive 802.11b, packet length=1024 byte, -80dBm	60	mA
Standby	0.9	mA
Deep Sleep	10	uA
Power save mode DTIM 1	1.2	mA
Power save mode DTIM 3	0.86	mA

2.6 Summary

Based on the literature review above, it can be seen that many researches on sensor-based environmental monitoring and controlling systems has been conducted. Most of the systems discussed previously do not allow monitoring and controlling via a graphical user interface. In addition, low cost implementation of Internet of Things for control and monitoring in mushroom agriculture sector could hardly be found. Also, many of the systems available in the market is not designed specially for mushroom cultivation but for general environment monitoring and control.

To resolve this problem, this project proposes a system that monitors and controls the four important environment factors for mushroom agriculture: temperature, humidity, carbon dioxide and light intensity. It has a graphical user interface developed using Thingspeak, with the implementation of Internet of Things using ESP 8266 series Wi-Fi module.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the methodology of development of the agriculture interface circuit. The interface circuit has the capability of monitoring and controlling the environmental condition for mushroom farm remotely, bringing the concept of Internet of Things (IoT) to agriculture.

Section 3.2 gives an overview of the project. Section 3.3 discusses about the hardware implementation. In section 3.4, the software implementation is discussed. In section 3.5, the software development is presented. In section 3.6, the performance-testing procedures are discussed. Finally, section 3.7 presents a summary of the methodology chapter.

Figure 3.1 shows the flow chart of development of the project. Firstly, the system functionality will be designed. Then, the interface circuits will be designed and built one by one. The first interface circuit to be designed will be the interface circuit of temperature and humidity sensor, followed by the interface circuit of light-dependent resistor and interface circuit of CO2 sensor. Next, the source code will be drafted. Then, the system will be combined and tested to see if it fulfills the requirement. If the system is not working as expected, the interface circuit will be modified and source code will be revised. The troubleshooting process will be repeated until the system worked well and fulfilled its requirements. Lastly, results will be evaluated.

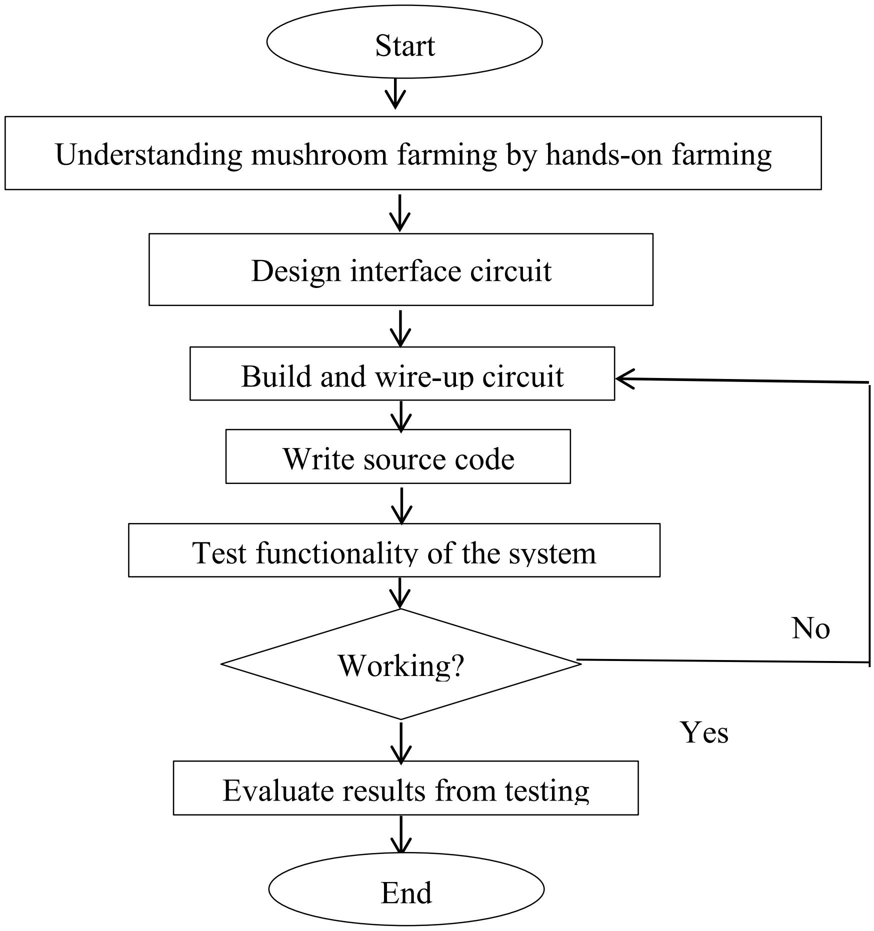

Figure 3.1: Flowchart of the development of this project.

3.2 System Overview

The system consists of two main parts: the monitoring system and the control system. The monitoring part starts with data acquisition from the temperature and humidity sensor, carbon dioxide sensor and LDR (Light Dependent Resistor) using Arduino Uno. The data is then sent to the Cloud. The graphs of temperature, humidity, carbon dioxide concentration and light intensity can be viewed using ThingSpeak. ThingSpeak is an online interface for IoT projects. The control system includes processing data acquired from the sensors and controls appliances such and humidifier, fan and light to regulate the environment inside the mushroom farm according to the mode of environment selected. There are three modes of environment: spawn-run, pin head initiation and cropping. Different modes have different set of required environmental conditions. The environmental conditions in different operating modes are shown in Table 3.1.

Table 3.1: Environmental conditions in different operating modes.

	Spawn-run mode	Pin head initiation mode	Cropping mode
Humidity	90%RH	95%RH	85%RH
Temperature	25°C	19°C	20 to 25 °C
Carbon dioxide	20,000ppm	600ppm	Less than 600ppm
Light	Off	2,000lux for 12 hours	>500lux for 12hours

The overall system architecture of the project is shown in Figure 3.2. The sensors, humidifier, fan and LED (Light Emitting Diode) placed in the mushroom farm are connected physically to the control unit, which consist of the Arduino Uno and the Wi-Fi module ESP 8266. The ThingSpeak online user interface, laptop, and mobile phone will be connected to the control unit wirelessly.

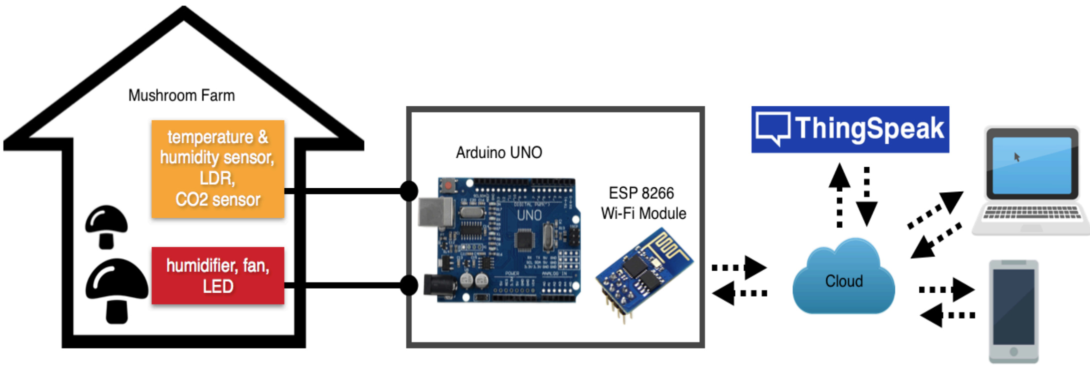

Figure 3.2: Overall System Architecture of the project.

3.3 Hardware Implementation

3.3.1 Arduino Uno as Microcontroller

The main controller used in the system is Arduino Uno. The Arduino Uno is a microcontroller board based on the ATmega328. It consists of 14 digital input/output pins, of which 6 can be used as PWM outputs, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. Figure 3.3 below shows an Arduino Uno microcontroller.

Figure 3.3: Arduino Uno ATmega328.

This Arduino board consist of I2C bus, that is able to transfer the data from Arduino board to the output devices. It is programmed over RS232 serial interface connections with ATmega Arduino microcontrollers. The operating voltage is 5 volt. The input voltage recommended for Arduino microcontroller is from 7v to 12v. The DC input current to the Arduino board is not more than 40mA.

Arduino Uno is chosen in this project because it is reliable, low-cost, and it has sufficient IO ports for my project. It is also user-friendly and allows complex electronic systems to be designed in a short time frame.

3.3.2 Measuring Temperature and Humidity

A DHT22 sensor was used to measure the temperature and humidity in the mushroom farm. DHT22 utilizes exclusive digital-signal-collecting-technique and humidity sensing technology. It is small in size and has low power consumption. It allows long transmission distance of 20 meters and is suitable for all kinds of harsh applications. This compact sensor can measure both temperature and humidity, so it is ideal for measuring mushroom environmental condition.

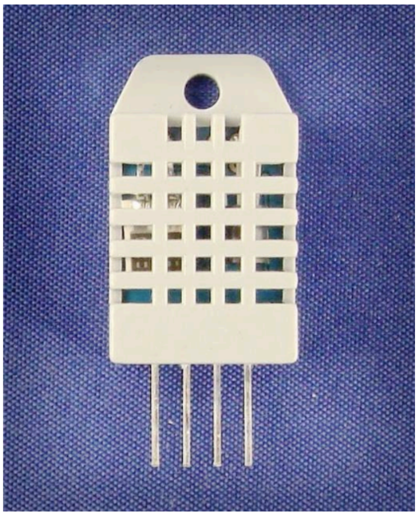

Figure 3.4: DHT22 temperature and humidity sensor.

To calibrate DHT22 sensor, it had to be exposed to extreme conditions. The sensor was kept in condition of temperature between 50 degrees Celsius and 60 degrees Celsius, humidity of less than 10%RH for two hours. Then, it was placed in condition of temperature between 20 degrees Celsius and 30 degrees Celsius, humidity of more than 70%RH for five hours. After the calibration, the sensor was powered on and its readings were compared with HTC-1 commercial temperature and humidity meter to ensure its accuracy.

The humidity and temperature values detected by the sensor were processed in Arduino UNO to determine the activity of the humidifier and fan. The values were then sent to the cloud via the Wi-Fi module, ESP8266.

3.3.3 Measuring Carbon Dioxide Concentration

MQ135 gas sensor is used to measure the carbon dioxide concentration in the mushroom farm due to its fast response, high sensitivity, and stable and long life. Figure

3.4 shows the typical sensitivity characteristics of the MQ-135 for several gases in temperature of 20 degree Celsius, humidity of 65%RH, Oxygen concentration of 21% and RL=20kΩ. Ro is the sensor resistance at 100ppm of NH_3 in the clean air, while Rs is the sensor resistance at various concentrations of gases.

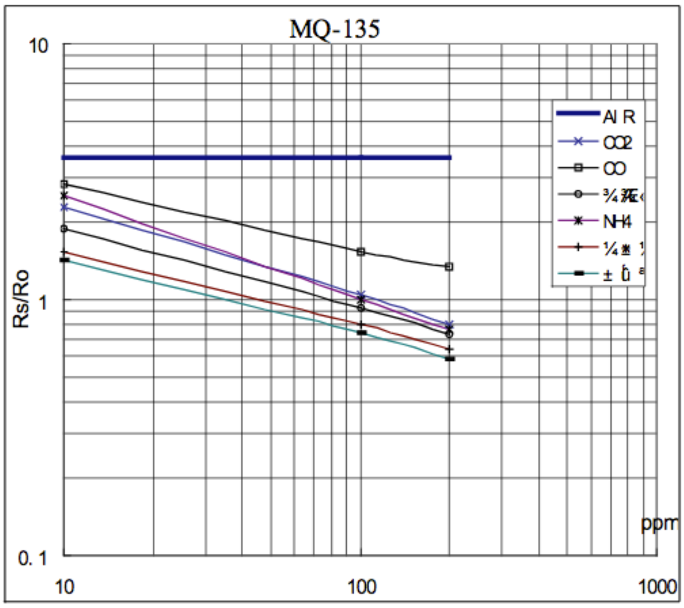

Figure 3.5: Typical sensitivity characteristics of the MQ-135.

Some calibration was done before the sensor is used to measure carbon dioxide concentration. The sensitivity curve from its datasheet shown in Figure 3.4 and is used as reference. From Figure 3.4, it is shown that the carbon dioxide concentration slope is a power function as shown in the equation

$$\mathrm{ppm} = a\left(\frac{\mathrm{Rs}}{Ro}\right)^{b} \tag{3.1}$$

From the equation, the values of a and b can be calculated. The function for carbon dioxide concentration obtained is as follow.

$$\mathrm{ppm} = 116.60207\left(\frac{\mathrm{Rs}}{Ro}\right)^{-2.76903} \tag{3.2}$$

By referring to http://co2now.org/, the amount of CO_2 gas in atmosphere was 409.01ppm. To measure the output resistance, Rs, the sensor was first heated for 24 hours and left in open air. The output resistance measured was 26962ohm. By substituting ppm and Rs values into equation (3.1), the value of Ro calculated was 42421ohm.

3.3.4 Measuring Light Intensity

A light dependent resistor (LDR) as shown in Figure 3.6 was used to measure the light intensity in the mushrrom farm. LDR is a sensor where its resistance is inversely proportional to the amount of light falling on it. To measure lux, some measurements and mathematical calculations had to be done, as the relationship between lux and resistance of an LDR is not linear.

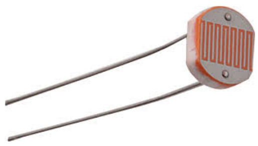

Figure 3.6: Light Dependent Resistor (LDR)

Firstly, an LDR and a lux meter were placed at the same place and ensure that same amount of light fall on the two sensors. Then, readings of the LDR resistance and the lux meter were recorded and plotted into a graph as shown in Figure 3.7.

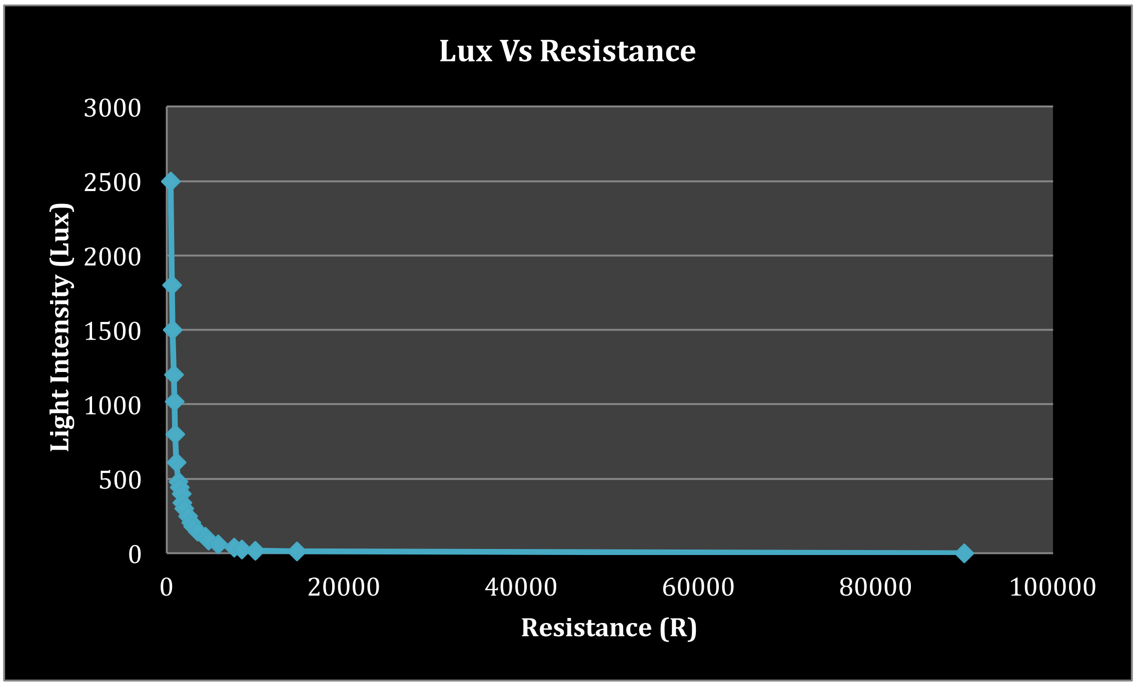

Figure 3.7: Graph of Lux as a function of Resistance.

From Figure 3.7, it could be seen that resistance decreases exponentially as the brightness of the light increases. To change the graph into a straight-line graph which can be described by the equation y = mx + b where m is the slope of the line and b is the y-intercept of the line. logarithm of both variables were calculated, and the graph was replotted as shown in Figure 3.8.

From the graph of log(R) vs log(lux), the following equation was obtained:

$$log_{10}(lux) = -2.273 \times log_{10}(R) + 11.260 \qquad (3.3)$$

Applying rules of logarithm, the following equation was obtained:

$$lux = 10^{b} \times R^{m} \qquad (3.4)$$

where m = -2.273; b = 11.260

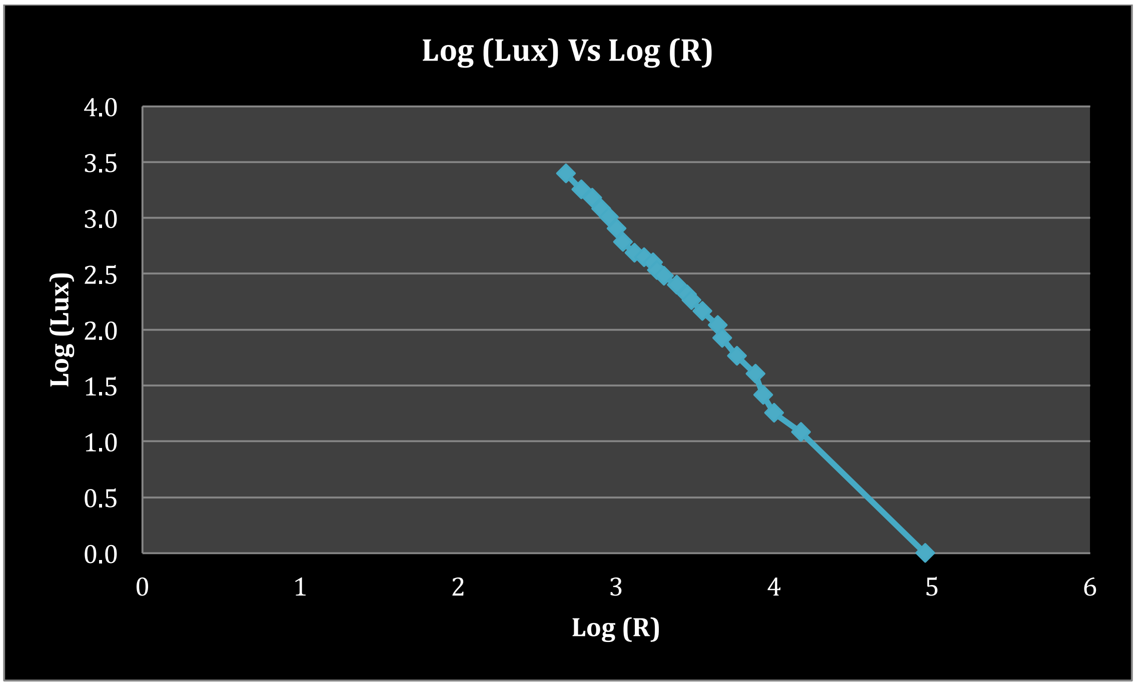

Figure 3.8: Graph of log(R) vs log(lux).

A circuit is built to measure the resistance of the LDR as shown in Figure 3.9. The measurements collected from the LDR were passed to Arduino Uno for processing. The measurements were computed its Lux value in the Arduino Uno. The algorithm code in Arduino Uno determines the activity of the LED lighting to control the increase or decrease of the room's Lux value. The Mushroom room's lux value was also sent to cloud using ESP8266 Wi-Fi Module for remote monitoring.

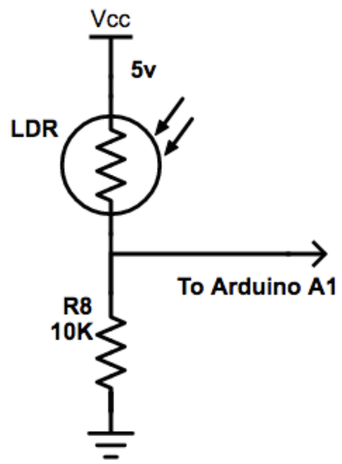

Figure 3.9: Schematic diagram of interface circuit for LDR.

3.3.5 Controlling AC Devices

Most of the electrical appliances are powered on by AC power supply. To control the appliances using a microcontroller, a solid state relay G3MB by Omron is used. The solid state relay G3MB, shown in Figure 3.10 was powered on by the microcontroller, and was controlled by an input control signal from the microcontroller. When the input signal is 0-2.5V, the relay was off, when the input signal is 3.3-5V, the relay was on. Live wire of the AC power supply was connected to the relay, and then to the power socket to supply current to the AC device.

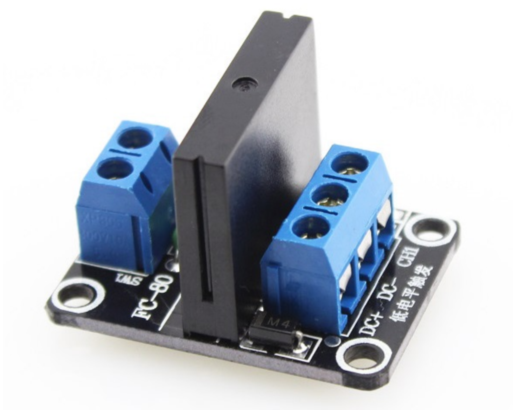

Figure 3.10: Solid state relay G3MB by Omron