INTERNET OF THINGS FOR INDOOR FARMING

By

CHONG KAI CHIAN

150ACB3270

A REPORT

SUBMITTED TO

Universiti Tunku Abdul Rahman

in partial fulfillment of the requirements

for the degree of

BACHELOR OF INFORMATION TECHNOLOGY (HONS)

COMMUNICATIONS AND NETWORKING (CN)

Faculty of Information and Communication Technology(FICT)

(Perak Campus)

JANUARY 2018

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Date : 10th April 2018______________

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I would like to express my sincere thanks and appreciation to my supervisors, Dr. Goh Hock Guan who has given me this bright opportunity to engage in IoT-based project. It is my first step to establish a career in embedded network and IoT application. A million thanks to you and appreciate your helpful guidance along the project goes.

Then, I would like to thank my dearest course mate Johnson Khong, Chow Wen Chai and Low Kim Ching as they teach me lots for the study. Finally, I must say thanks to my parents and my family for their love, support and continuous encouragement throughout the course.

ABSTRACT

This paper proposed an indoor farming method integrated with the concept of the Internet of Things (IoT). The traditional agriculture might be vulnerable to the climate change. This is because, since the crops or plants are grown in an outdoor field, they are exposed to the natural environment. As they have their optimal temperature and conditions to grow, a climate change may bring a huge loss to the farmer because the productivity might have a significant drop as resulted by the climate change. At the same time, during traditional agriculture, most of the farmers are using their experience and prediction for the agriculture work and this may decrease the food productivity as well. Furthermore, the large-size field will requires more labour to manage the field but this does not guarantee an increase in food production.

Thus, indoor farming environment is designed to provide a stable condition which suitable for the plants or crops to grow. To achieve that, the concept of precision agriculture is a "MUST". By implementing different types of sensors such as the temperature and air humidity sensors, we will able to monitor the field parameters and these data will be sent to the Cloud for a real-time display purpose. At the same time, if the parameters are out of a pre-defined threshold value, the Raspberry Pi as the IoT gateway which receives the data from the sensors will issue the command to trigger the actuator in the field to make adjustment or control the abnormal parameter. On the other hand, the system will perform the irrigation system automatically by using the timers. To conclude, this project is expected to establish a smart environment that is suitable for indoor farming and able to reduce the labour cost and labour daily task yet increase the productivity and efficiency.

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LIST OF ABBREVIATION

3G	Third generation of mobile network
ADC	Analogue-digital-converter
CMS	Central Monitoring Station
CO_2	Carbon dioxide
COM	Commom
GPIO	General purpose input/output
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
GUI	Graphical User Interface
I^2C	Inter-Integrated Circuit
IoT	Internet of Things
NO	Normal Open
PA	Precision Agriculture
RFID	Radio Frequency Identification
RPi	Raspberry Pi
SDLC	System Development Life Cycle
SPI	Serial Peripheral Protocol
TCP/IP	Transmission control protocol/Internet protocol

Chapter 1: Introduction

The term “the Internet of Things” (IoT) was coined by Kevin Ashton, the co-founder of MIT’s Auto-ID Center in 1999 (Tozzi, C., 2016). IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The first idea of Ashton on IoT was focused on using radio frequency identification (RFID) technology to connect the devices together. But, now, IoT is primarily relies on IP networking for the information exchange between devices. This is because the introduction of IPv6 has resulted in a huge increase in address space and enables the humans to assign an IP address to every “thing” in order to let them communication to each other.

On the other hand, indoor farming is a way of growing the plants entirely indoors and it is usually related to greenhouse. This is because this farming method mostly deploys the artificial lights to replace the sunlight and implements some growing methods such as hydroponics to provide the plants the nutrients and other basic requirements for growth. This farming method has a significant improvement then before as the plants and crops are not exposed to the uncontrollable natural environment. Moreover, the scale can be large or small, and a wide variety of plants can be grown indoors such as the vegetables, herb, spices and fruits. With a more advance way, indoor farming nowadays is mostly related to the concept of precision agriculture.

As mentioned above, the precision agriculture (PA), is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. For examples, predictive analytics can be performed to make a smarter decision based on the real-time data on weather, soil and air quality, crop maturity and even equipment and labour costs and availability. PA is provisioned to improve the agriculture yields, reduce the fertilizer cost and pollution through poor use of chemicals and provide better information for management decision.

However, there is a key enabler to the previous mentioned PA in order to make the PA to function well. It is the sensor. Undeniably, the PA will uses numerous types of data such as the temperature, air and soil humidity and even the nitrogen content of the soil to perform the predictive analytics and also some follow-up action. Thus, the sensor is playing the most important role in the PA and cannot be replaced or ignored.

As summary, this project proposes an indoor farming method with the concept of IoT and PA. By implementing different types of sensors within the farming environment, the project system is expected to perform some automatic processes such as maintaining the temperature and humidity parameters, perform irrigation procedure and able to present the environment situation such as by an image and numerical values of the parameters to the user.

1.1 Problem Statements and Motivation

The traditional agriculture has few limitations in terms of the crop yields, the crop resilience to climate changes, the field size required and the labour cost.

The traditional agriculture may vulnerable to the food shortage crisis. This is because the farmers used to predict the crops' condition, the weather, the harvest time and other important aspects based on their working experiences. However, these working experiences and predictions are not always correct and perfect. Sometimes, it will results a poorer performance in terms of the productivity and quality of crops. According to the Michele, Fabio and Cynthia (2012) (Research Gate. ,2012), the world population is estimated to be more than 9 billion people as shown in Figure 1-1-1. This statement means that the farmers will face a big challenge to increase the food production in order to feed the growing world population.

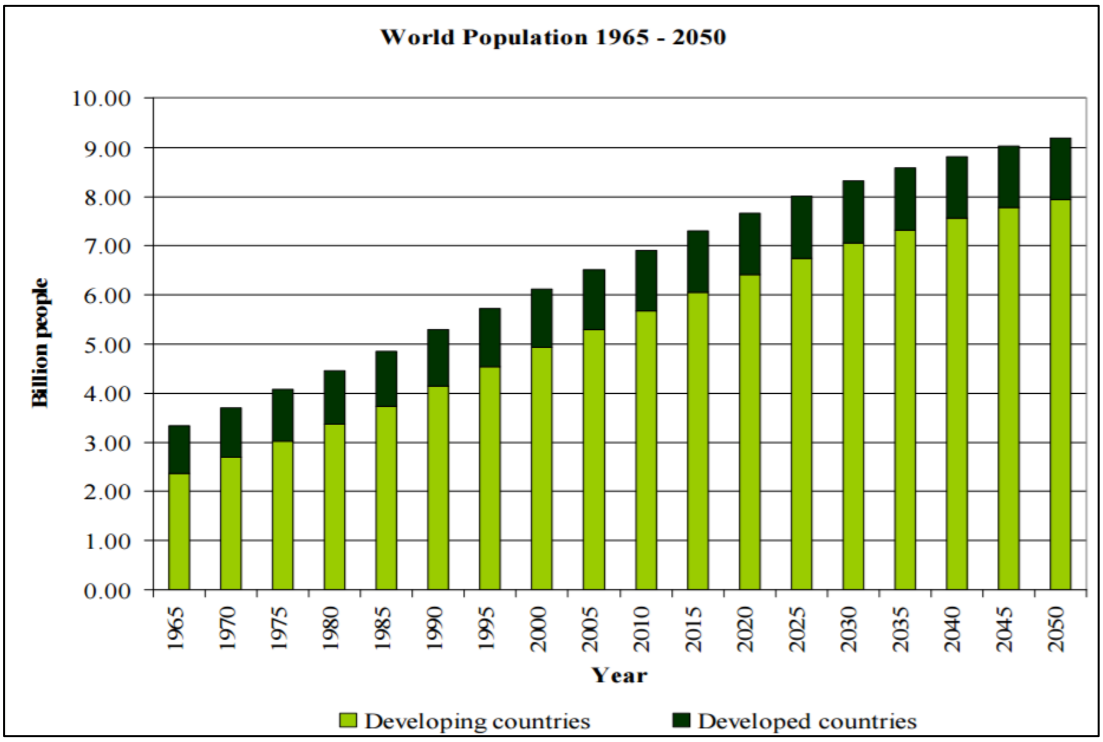


Figure 1-1-1: The world population from 1965 to 2050

Furthermore, the crops in the outdoor field are vulnerable to the climate change. Every plants are having their specific living environment' requirements respectively and these requirements can eventually affect the food supply significantly. The reason is that the changes of optimal temperature for crops' growth due to the climate change will lead to the decline of crop yields. For instant, the premature budding due to a warm winter caused $220 million in losses of Michigan cherries in 2012. (National Climate Assessment, 2014)

Besides that, during traditional agriculture, the plantation field size is very huge. This is a challenge to future agriculture as more and more free spaces need to be developed into plantation field for agriculture purposes only. However, the production of food might not directly proportional to the increase of plantation fields due to certain reason such as the climate changes mentioned above. At the same time, a large field would require a large number of labours during the monitoring process. To conclude, the traditional agriculture might be inefficient in terms of the land utilisation and labour cost.

1.2 Objectives

As to enhance the situation that traditional agriculture encountered, lot of efforts has been done for improvement. The objectives of this project are:

1. To establish an indoor farming environment.
2. To provide the real-time monitoring system on crops and farming environment parameter.
3. To establish a simple user interface for the users to view the data and control the environment remotely.
4. To provide an automatic irrigation system.
5. To reduce the labour daily duty.
6. To implement simple analytics and produces helpful information for decision making.

Since the indoor farming environment will implement the concept of precision agriculture, there is a need to capture and record the environment situation and their changes from time to time. Thus, the sensors will play their roles to gather their respective data and send to the central control unit. The control unit will then further sending the data to the Cloud for storage and provide and a simple user interface to the user. The user interface provides an interaction method to the user to monitor the farm and perform some control mechanism such as to change the environment parameter explicitly. At the same time, the system will implement an automatic irrigation system with a timer manner and other control-modules controlled by the control unit. It is expected to reduce the labour daily duty such as to monitor and water the crops with lesser efforts and time-consumed. Furthermore, the system is expected to perform some simple analytics based on the data captured and produce the helpful information for decision making such as to determine whether the environment parameters suitable for certain type of crops or are the crops ready to be harvest.

1.3 Project Scope

In this project, it mainly focuses to 3 major parts which are to build a real-time monitoring system, a simple GUI for the user and a remote-control system.

For the real-time monitoring system, the sensors will be allocated at specific points within the indoor farming area. The sensors are connected to the central control unit. Each time the sensors successfully captured the data, they will send the data to control unit and the control unit will be responsible to send it to the Cloud. For the information, the data captured would relate to the temperature and air humidity. These data will then be shown to the user through the user computer with the GUI.

From the perspective of user, the data is kept in a Cloud service provider named dweet.io and it can be used to show the data and information sent by the sensor nodes. The system is having a simple GUI to show the data and giving the user an option to make adjustment to the environment condition such as the temperature. At the same time, the system is expected to implement the data analysis to produce some meaningful information which is useful for decision making.

Back to the indoor farming area, the camera module and irrigation system are perform in a timer-manner such that the camera will take screenshot every specific period of time whereas the soil moisture sensor will detect the soil moisture every few seconds to activate or deactivate the irrigation system.

1.4 Expected Contribution from the Project

According to Chakraborty and Newton (2011), in order to meet the demand of the world's population by 2050, the global food production must increase by 50%. In his words, 25% of the world's cereal production will be affected by the climate change as it will increase the uncertainty over the availability of water and affecting the pests and pathogen impacts. Also, it might destroy they optimal growth environment for the crops. Thus, this project suggest a stable indoor farming environment which does not vulnerable to climate change and a system used to control the farming environment which provide the increase the productivity and work efficiency of the labour.

Firstly, instead of using the experience to make predictions, the sensors provide the farmers a more reliable statistic which is closed to the actual value of the critical information such as the environment temperature for decision making process. Then, the indoor farming environment can be designed with control feature to enable the remote-controlling of the environment condition. As an example, if the sensors detect the temperature is not within the optimal temperature, the system is able to adjust the temperature back to the normal level. Moreover, on one hand, indoor farming of PA by vertical farming is small-field-size friendly, yet no worries about the expose to sunlight because sufficient artificial light is provided to the plants. On the other hand, the monitoring task can be handled by the sensors which will be more efficient and effective compared to the performance of labours.

1.5 Report Organisation

The remainder of this report is organised as follows: In Chapter 2, the existing system and technologies are introduced. Chapter 3 has shown system methodology which included the system development model, system and functional requirements, cost, and project timeline. In Chapter 4, the system design and the current implementation of system with functional modules' details are shown. In Chapter 5, details of setting up the system are elaborated. In Chapter 6, the system performance is evaluated. Lastly in Chapter 7, conclusion is and recommendations on future improvement are made.

Chapter 2: Literature Review

2.1 IoT infrastructure

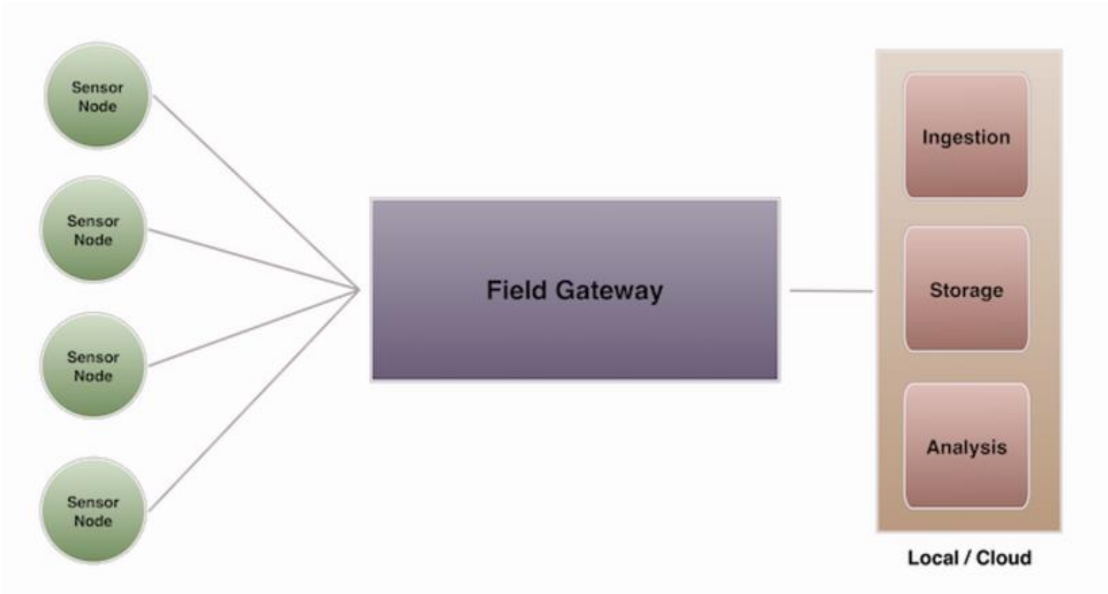


Figure 2-1-1: IoT Infrastructure. (MSV, 2015)

The IoT infrastructure can be classified into 3 stages as shown in Figure 2-1-1: the sensors/actuator, the IoT gateway, and data centre/Cloud.

For the stage 1, the sensors collect data from an object or the environment and turn it into the useful and meaningful data. On the other hand, the actuator changes the physical conditions that generate data. For an instance, shut off a power supply, adjust an air flow valve and etc. This stage enables many IoT applications such as the camera module in monitoring system, air quality monitoring and temperature control. For the information, the sensors network can be wired or wireless with their strength and limitation respectively. Since the data is the core of the IoT technology, the data processing is important and it can occur in all three stages. However, the data processing in sensors are limited by the processing power of the device that the sensors attached to. Thus, a more extensive processing would be made in stage 2 or stage 3.

Then, for the stage 2, the sensor nodes will send the data to a central location via low-energy radio communication network such as the ZigBee. The central location that aggregates the raw data generated by during the stage 1 is called an IoT gateway. The IoT gateway works by receiving data from IoT sensors, which it can then send onwards to the cloud; it also receives information from the cloud which then forward it back to the actuator to help it performs some control functions such as regulating environmental changes. All information moving from stage 1 to stage 3, or vice versa, goes through the connected IoT gateway. By managing this connection, the gateway can perform security tasks, help manage devices and translate protocols.

Lastly, stage 3 refers to the data centre or Cloud. Data that needs more in-depth processing are forwarded to physical data centre or cloud-based systems, where more powerful IT systems can analyse, manage, and securely store the data. Besides that, the integration of the dashboard service with the Cloud enables the visualisation of those data to the user.

2.2 Raspberry Pi

Figure 2-2-1: Raspberry Pi 2 Model B (Rhydolabz.com, 2015)

The Raspberry Pi is a series of small single-board computer which developed by the Raspberry Pi Foundation in United Kingdom. It act as an important platform to develop the IoT project.

Here are the features of the Raspberry Pi 2 Model B:

- 4 USB ports
- 40 GPIO pins
- Full HDMI port
- Ethernet port
- Combined 3.5mm audio jack and composite video
- Camera interface
- Display interface
- Micro SD card slot
- VideoCore IV 3D graphics core

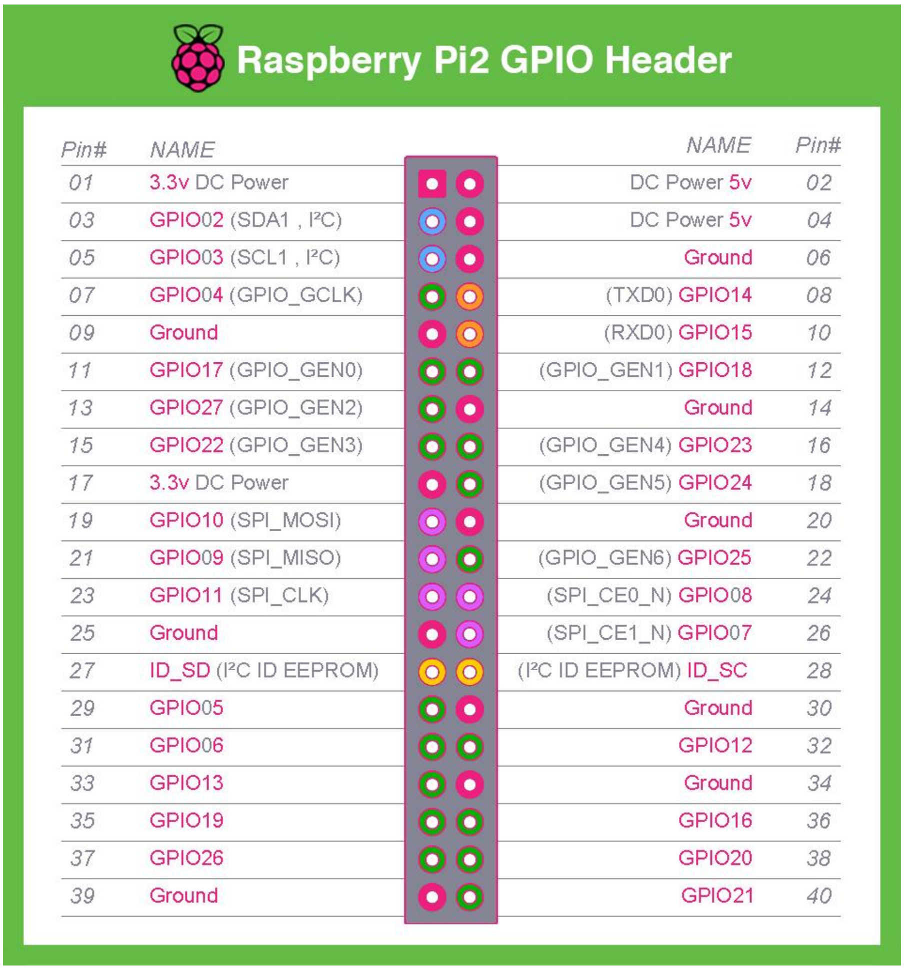


Figure 2-2-2: Raspberry Pi 2 GPIO pin diagram. (Rhydolabz.com, 2015)

Refer to the Figure 2-2-2, the Raspberry Pi 2 is having 40 GPIO pins. It provides 3.3v and 5v power DC power. The Raspberry Pi also support 2 type of protocol which are SPI and I^2C.

The **Serial Peripheral Protocol (SPI)** defined the external microcontroller bus, used to connect the microcontroller peripheral with 4 wires (spi).

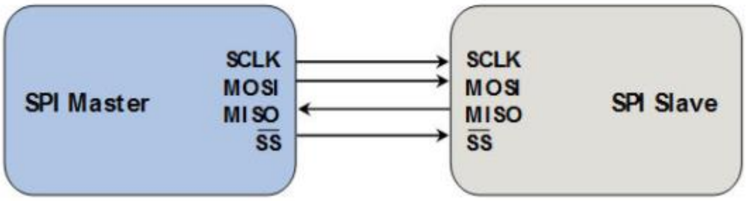


Figure 2-2-3: SPI bus topology. (Byteparadigm.com, 2017)

The 4 signal lines shown in are:

- SCLK is the clock signal sent from the bus master to all slaves.
- MOSI is the data line from master to slave.
- MISO is the data line from slave to master.
- SS is the slave select signal that used to select the slave the master communicates with.

SPI is a single-master communication protocol. When the SPI master wishes to send data to a slave and/or request information from it, it selects slave by pulling the corresponding SS line low and it activates the clock signal at a clock frequency usable by the master and the slave. The master generates information onto MOSI line while it samples the MISO line.

On the other hand, **Inter-Integrated Circuit ($\mathbf{I^2C}$)** is a multi-master protocol that uses 2 signal lines which are the "serial data" (SDA) and "serial clock" (SCL). The I^2C bus consists of SDA and SCL active wires and a ground connection. The active wires are both bi-directional and the protocol specified that the IC that initiates the data transfer on bus is considered as the master. At that particular time, all other ICs on the same bus are regarded as the slaves.

2.3 Light Spectrum

All Green plants contain a pigment called chlorophyll in chloroplast and the chloroplasts are found in their leaves. The main use of the chlorophyll to a plant is that it will absorb sun light to be used during the photosynthesis. As detailed, the chlorophyll will absorbs certain wavelengths of light within the visible light spectrum such as the red light (long wavelength) and blue light (short wavelength) while it will reflected the green light thus making the plant appear green.

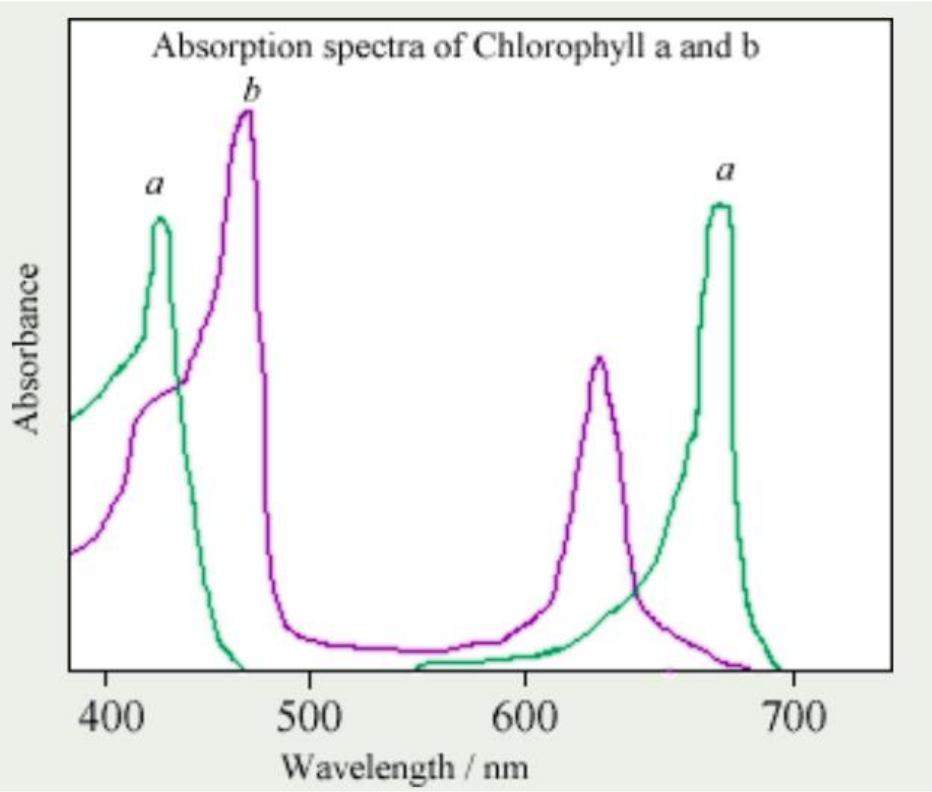


Figure 2-3-1: Absorption spectra of Chlorophyll. (Webexhibits.org., 2008)

From Figure 2-3-1, we can observe that the green plants best absorbed the red (about 465nm) by chlorophyll b and blue light (about 665nm) by chlorophyll a. Thus, in the proposed system, the floodlight that is emitting the purple light which comprised the red and blue light is used to act as the artificial light for the plant.

2.4 Review on the Existing Systems/Applications

In this section, 4 existing system have been review for the WSN monitoring system.

1. Application of Wireless Sensor Networks for Greenhouse Parameter Control in Precision Agriculture. (Chaudhary, Nayse and Waghmare, 2011)
2. Precision Agriculture Monitoring System using Wireless Sensor Network and Raspberry Pi Local Server. (Flores et al., 2017)
3. Design and Simulation of a Wireless Sensor Network Greenhouse-Monitoring System Based on 3G Network Communication (Zhou, Y. and Duan, J. ,2016)
4. Wireless Sensor Based Remote Monitoring System for Agriculture Using ZigBee and GPS (G. V., S. and SD, M., 2013)

2.4.1 Application of Wireless Sensor Networks for Greenhouse Parameter Control in Precision Agriculture

This journal article proposed the use of Programmable System on Chip Technology as a part of Wireless Sensor Network. There are three type of sensors used which are the outside climate sensor that gather the data of wind flow, wind direction, temperature, humidity and percentage of carbon dioxide; the inside climate sensor that monitor the same data as last mentioned sensor but inside the greenhouse; the soil sensor to detect the soil condition.

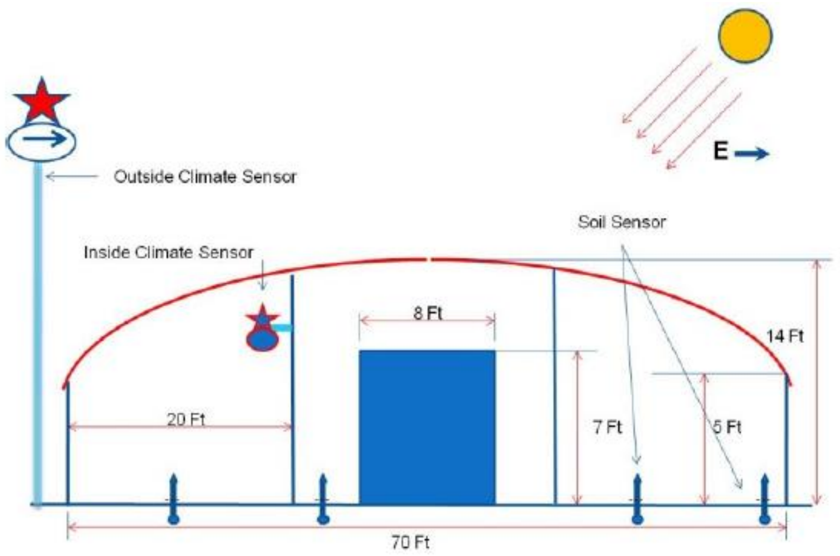


Figure 2-4-1-1: Sensor and structure of greenhouse.

In their prototype greenhouse, the greenhouse size is 70m x 150m and required 40 to 50 wireless nodes. The sensor nodes will send information to the central node. They have combine 802.11, 802.15.4 and 802.15.5 in their wireless communication. The application based wireless sensor network with a specific protocol and system on chip based hardware with programmable radio is able to overcome the data congestion and intercommunication between nodes.

For the temperature and humidity control, this paper uses forced-air heaters as the heating system as well as the dehumidifier. On the other hand, the soil condition such as the soil temperature and moisture are control by the irrigation system.

2.4.2 Precision Agriculture Monitoring System using Wireless Sensor Network and Raspberry Pi Local Server

This paper introduce an wireless sensor network to gather the field data of temperature, humidity, moisture, luminosity, electrical conductivity and pH using various type of sensors with the Raspberry Pi as the local server which used for data processing and transfer.

All the sensors are connected to single microcontroller board with a mounted Xbee shield for wireless communication. The RF transmission between the sensors and the Raspberry Pi is handled by the XBee module and its transmission is set to five minutes interval. The sensors collect the data and sent the data to the Raspberry Pi, then enter to sleep mode. When the Raspberry Pi receives the data, it stores it into the local database, and then forwards the data to the main server via the Internet. To visualize the data, a website is specially designed with a combination of PHP and HTML scripts.

2.4.3 Design and Simulation of a Wireless Sensor Network Greenhouse-Monitoring System Based on 3G Network Communication

This paper proposes the WSN for the real-time monitoring of the temperature, humidity, light and carbon dioxide (CO_2) concentration based on the third-generation (3G) network communication.

For the design scheme of this paper, the data collected by multiple terminal nodes are transmitted to the monitoring centre through the AP node based on the infrastructure network model and the transmission control protocol/Internet protocol (TCP/IP). The terminal nodes are the sensors whereas the AP node is responsible for transmitting the data from terminal nodes to the monitoring host.

In this paper, since all nodes in the system work in the same channel, only 1 terminal node and 1 AP node exist for each communication under a time control. When the time is full, the sensor is dormant and change to unconnected state.

2.4.4 Wireless Sensor Based Remote Monitoring System for Agriculture Using ZigBee and GPS

In this paper, the researchers implemented WSN and monitoring system by using the ZigBee, GPRS, GSM and GPS technologies as shown in Figure 2-4-4-1. ZigBee is used in connecting the WSN to a central node, GPRS or GSM is used in connecting the central node to the Central Monitoring Station (CMS). At the same time, GPS parameters related to the field are sent to the CMS as well in order to help in finding the location of the agriculture field location.

In this approach, the data is stored in local temporarily and in a Web database server. Besides that, the GPRS module is control to achieve the function of sending SMS or MMS alarm to the managers when an exception occurs with the field of monitoring field.

Nevertheless, the most significant difference of this paper from the others is that the gateway node is solar energy power supplied instead of using normal power supply.

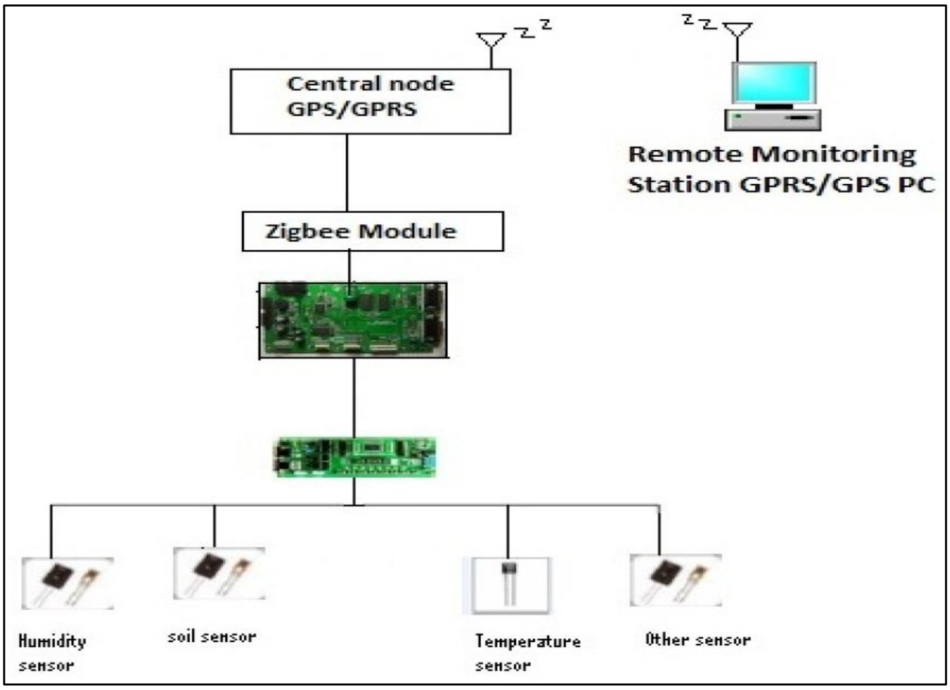


Figure 2-4-4-1: The proposed system architecture in section 2.4.4

2.5 Critical remarks of previous works

In this section, critical remarks of the 4 literature review papers are done and summarized in Table 2-3-1.

Paper 1: Application of Wireless Sensor Networks for Greenhouse Parameter Control in Precision Agriculture. (Chaudhary, Nayse and Waghmare, 2011)

Paper 2: Precision Agriculture Monitoring System using Wireless Sensor Network and Raspberry Pi Local Server. (Flores et al., 2017)

Paper 3: Design and Simulation of a Wireless Sensor Network Greenhouse-Monitoring System Based on 3G Network Communication (Zhou, Y. and Duan, J. ,2016)and Duan, J. ,2016)

Paper 4: Wireless Sensor Based Remote Monitoring System for Agriculture Using ZigBee and GPS (G. V., S. and SD, M., 2013)

Table 2-5-1: Summarized strengths and limitations of previous works

Paper	Strength	Limitation	Comments
1	• High flexibility • Able to overcome data congestion	• Limited battery • Available bandwidth might not enough if number of the parameters still increase.	• Deploy a variety of parameter monitoring and control. • Lack of display or visualization of data and information to the user.
2	• Low cost • Monitoring area can be extended to large size. • High flexibility	• The sensors are exposed to outdoor environment and require special protection. • The transmission interval has to be	• As wireless sensor has limited battery, the sampling or transmission interval has to be defined carefully.

		defined carefully.	• Lack of parameter control mechanism.
3	• High speed data transmission • Low power dissipation • Stable operation	• Division of 3G technology occur: - W-CDMA (Europe) - CDMA2000 (USA) - Time-division synchronous CDMA (China) • Interference and noise exist	• Lack of parameter control mechanism.
4	• Low cost • Low power consumption • Low complexity • Solar power supply for gateway node	• Low data flow • Star and Tree topology may lead to network failure	• Lack of parameter control mechanism. • Solar power supply is a good and stable way to ease the problem of limited battery.

Chapter 3: System Methodology

3.1 System Development Models

The software development of this project is related to study, design and develop an indoor farming environment which includes the monitoring system, a simple GUI for user to view the monitoring data with remote-control feature.

3.1.1 Agile Model

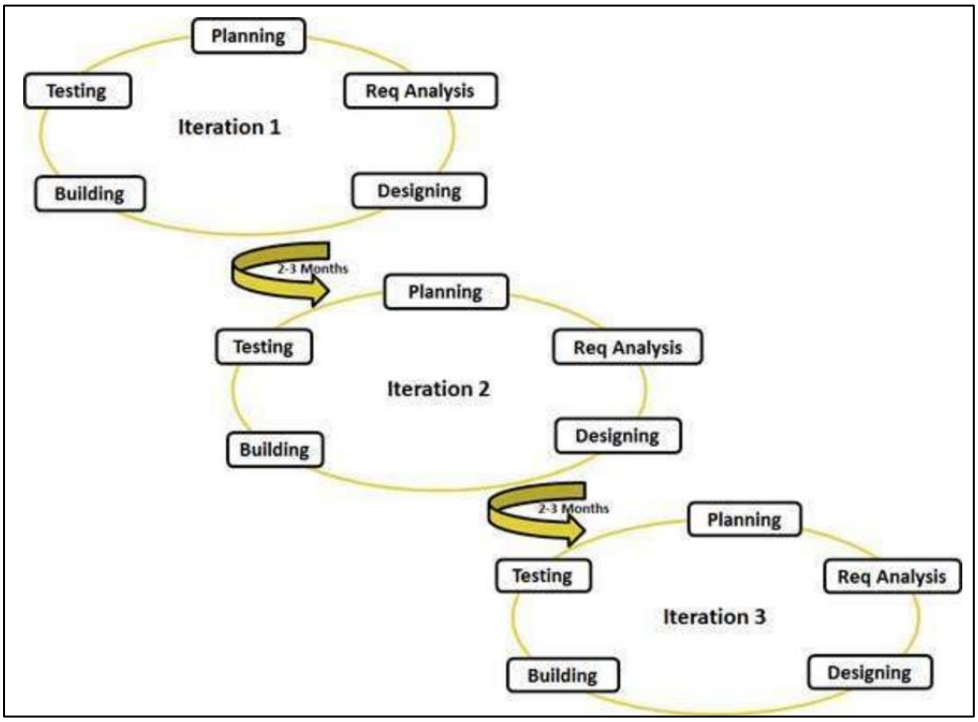


Figure 3-1-1: The agile system development life cycle (SDLC) model

The software development life cycle throughout the project lifetime will based on the Agile SDLC method as shown in Figure 3-1-1.(tutorialspoint. ,n.d.). This is a combination of iterative and incremental process models with focus on process adaptability. This agile method will break the project into smaller incremental builds, then iterative approach is taken and working sub-system is delivered after each iteration.

The advantages of the agile model are having shorter iterations can reduce complexity and risk, the functionality can be developed rapidly and demonstrated, resource requirements are minimum and little or no planning required. On the other hand, the disadvantages of this model are it is not suitable for handling complex dependencies, it brings more risk of sustainability, maintainability and extensibility, it requires a strict delivery management dictates the scope, functionality to be delivered, and adjustments to meet the deadlines and an agile leader or project manager is necessary,

3.1.2 Waterfall Model

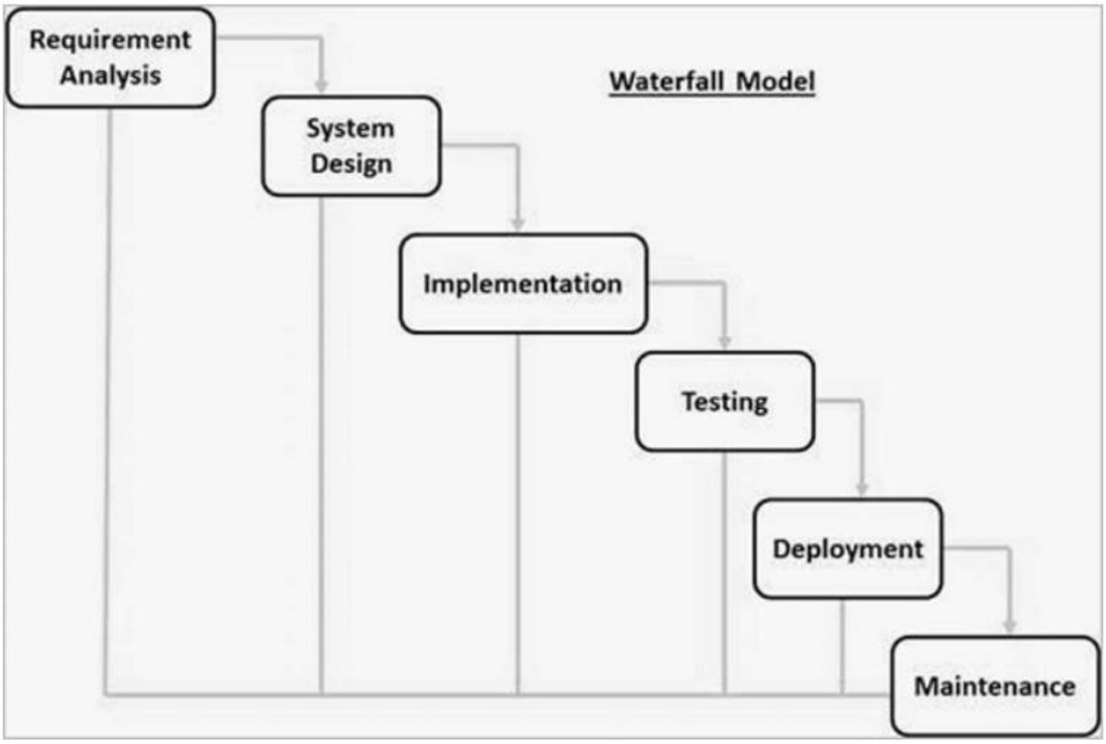


Figure 3-1-2: The waterfall system development life cycle (SDLC) model. (www.tutorialspoint.com., n.d.)

The waterfall model is the first process model to be introduced and it simple to understand and use. In this approach, the whole system life cycle is divided into separate process and the outcome of one phase will become the input for the next sequential process.

The advantages of this SDLC model are it is easy to manage, process are completed one at a time with clearly defined stages, easy to arrange task and works well for smaller project that requirements are well understood.

However, this linear-sequential life cycle require one phase must complete in order to begin the next phase and this might raises a high amount of risk and uncertainty along the project lifetime. Then, no working software is produced until late during the life cycle and it cannot accommodate the changing requirement. Moreover, adjusting scope during the life cycle can end a project.

3.1.3 Selected Model

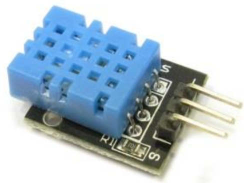
After considering the agile and water model in section 3.1.1 and 3.1.2, the agile model will be chosen as the software development life cycle throughout the project lifetime.

As related to this project, the software development will firstly started with the designing of the monitoring system and further break it down into sub features to perform its SDLC such as to develop and test its functionality, then new SDLC of implementing monitoring system on the farming area, followed by new SDLC of sending out the data collected to cloud and so on to include the other functionality. In this way, there is no detailed planning and there is clarity on future tasks only in respect of what features need to be developed. The feature driven development adapts to the changing product requirements dynamically and is tested very frequently, through the release iterations, minimizing the risk of any major failures in future. And, it can deliver early partial working solutions and enables concurrent development and delivery within an overall planned context.

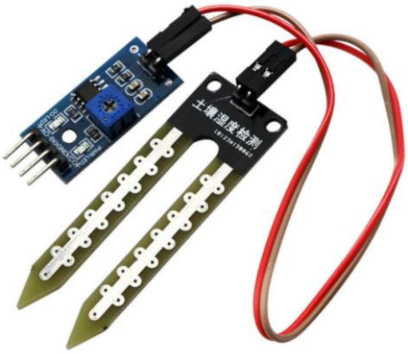
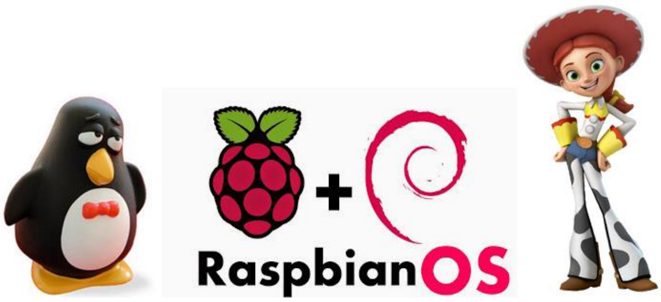
3.2 System Requirement

The hardware and software components of system requirements are shown in Table 3-2-1:

Table 3-2-1: Hardware and software requirements of this project

Hardware	
Raspberry Pi 2	
DHT11 sensor	
2 DC Fan	
Camera (Logitech Webcam C270)	

Wifi dongle	
Flood light	
Power supply machine	
9v DC Motor	

FC-28 Soil Moisture Sensor	
4-Channel relay	
Water pump pipe (4mm x 1meter)	
Software	
Raspbian Jessie	

MobaXterm	

For the hardware requirement, Raspberry Pi 2 will be used as the central control unit that running the python program and control the power supply to the sensors, camera, 9V motor and fan switch. To connect to the Internet in order to push the sensor data, the Raspberry Pi 2 needed to connect to a wifi dongle. For the sensors deployed, the DHT11 sensor is used to sense the temperature and air humidity whereas the FC-28 soil moisture is used to detect the presence of water in the soil. Furthermore, the fans and motor are provided 9v DC power by the power supply machine. Moreover, the flood light is used as the artificial light for the plants.

On the other hand, the softwares needed are open source and free to download. The Raspbian Jessie is the operating system used in the Raspberry Pi 2. Then, the MobaXterm is used to connect the Raspberry Pi with monitor via a SSH connection.

3.3 Functional Requirement

The system shall sense the temperature and air humidity data from time to time. Once the changes of the data have shown that either one of them has exceeded the pre-defined threshold values, the fans will turn on to reduce the temperature and air humidity level by using the air-circulation. Before integrate the sensors into the system, the functionality of the sensors are tested respectively.

The system shall sense the moisture level of the soil such that to drive the motor to activate the irrigation system when the soil is too dry or deactivate the irrigation system when the soil is not dry anymore.

The system shall capture a screenshot of the plant with a periodically manner and display the image to user via a web browser.

The system shall display the real-time data trend to user for monitoring purpose.

3.4 Project Milestone

The current project timeline of FYP 1 and the expected FYP 2 project timeline is shown in Table 3-5-1 and Table 3-5-2.

Table 3-4-1: The Gantt chart of project task during FYP 1.

Project Task	**Project Week**													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Determine FYP title	■													
Information collecting		■	■											
Determine objective & project scope			■											
Literature review				■	■									
Determine system requirement					■	■								
Generate system prototype						■	■	■	■	■	■			
System testing & finalize the report											■	■	■	
FYP 1 documentation		■	■	■	■	■	■	■	■	■	■	■	■	■
FYP 1 presentation														■

Table 3-4-2: the Gantt chart of project task during FYP 2.

Project Task	Project Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Plan, Design & Implement the camera module	■													
Test the camera module		■												
Plan, Design & implement the irrigation system			■											
Test the irrigation system				■										
Determine other possible functionality				■	■									
Grow different plants in the field				■	■	■	■	■	■	■	■			
FYP 2 documentation		■	■	■	■	■	■	■	■	■	■	■		
FYP 2 presentation													■	■

3.5 Cost and Budget

Table 3-5-1: Cost plan.

Item	Quantity	Expected Price	Supplied by UTAR
Raspberry Pi 2	1	RM 309. 14	Yes
DHT11 sensor	1	RM 13. 50	Yes
DC fan	2	RM 9. 87	Yes
Camera	1	RM 46. 00	Yes
Wifi dongle	1	RM 16. 00	Yes
UV Floodlight	1	RM 21. 90	Yes
Power supply machine	1	RM 449. 44	Yes
Single core wire	1	RM 43.80 (per 100 meters)	Yes

9V DC Motor	1	RM 26.50	Yes
FC-28 soil moisture sensor	1	RM 8.10	Yes
Water pump pipe (4mm x 1meter)	1	RM 1.50	Yes
Total		RM 945. 75	
Total in this project		RM 0. 00 (all supplied by UTAR)	

All the hardware needed is provided by Universiti Tunku Abdul Rahman (UTAR). The expected item prices are obtained from *www.lazada.com.my* and *www.mybotic.com.my*.On the other hand, the software needed are open source and can be obtained freely by online.

3.6 Concluding Remark

To conclude, agile system development life cycle is chosen to develop the system throughout the whole FYP life cycle. The system requirements are stated in order to build the system in current FYP 1 and for the coming FYP 2. Project timeline and budget are stated as well so that the project can be delivered in time with a controlled budget.

Chapter 4: System Design

4.1 System Architecture

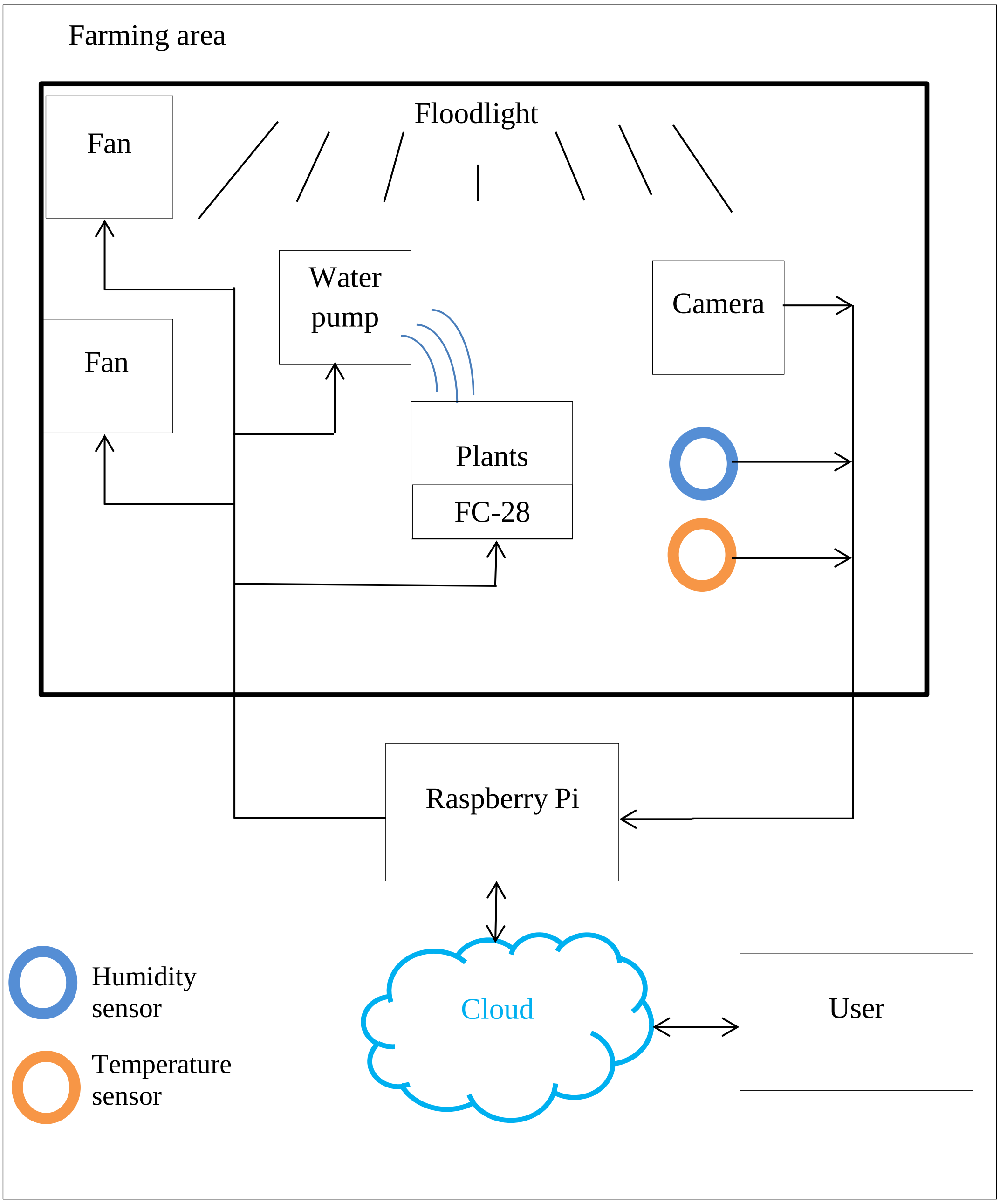


Figure 4-1: System overview.

From Figure 4-1, the system consists of three sensors which are humidity and temperature sensor, a soil moisture sensor and other components such as a camera, a flood light, two dc fans, a water pump and a centralized control unit of Raspberry Pi. For a brief system procedure, the sensors will keep reading the temperature and humidity of the farming environment and detect whether the soil is dry whereas the camera will captures the image of the plants condition and they will send the readings and image to the Raspberry Pi. Then, the Raspberry Pi will push the data to the Cloud. At the same time, the Raspberry Pi as central control unit, it will analyses whether the temperature or humidity value is still underlying within the predetermined threshold value in order to control the fan such as turn on the fan when the temperature is too high. On the other hand, the Raspberry Pi will control the water pump to water the plant which triggered by the FC-28 moisture sensor. Since the data are push to the Cloud, the user can view the data by accessing to the Cloud.

4.2 Functional Modules in the System

4.2.1 The Sensor Module

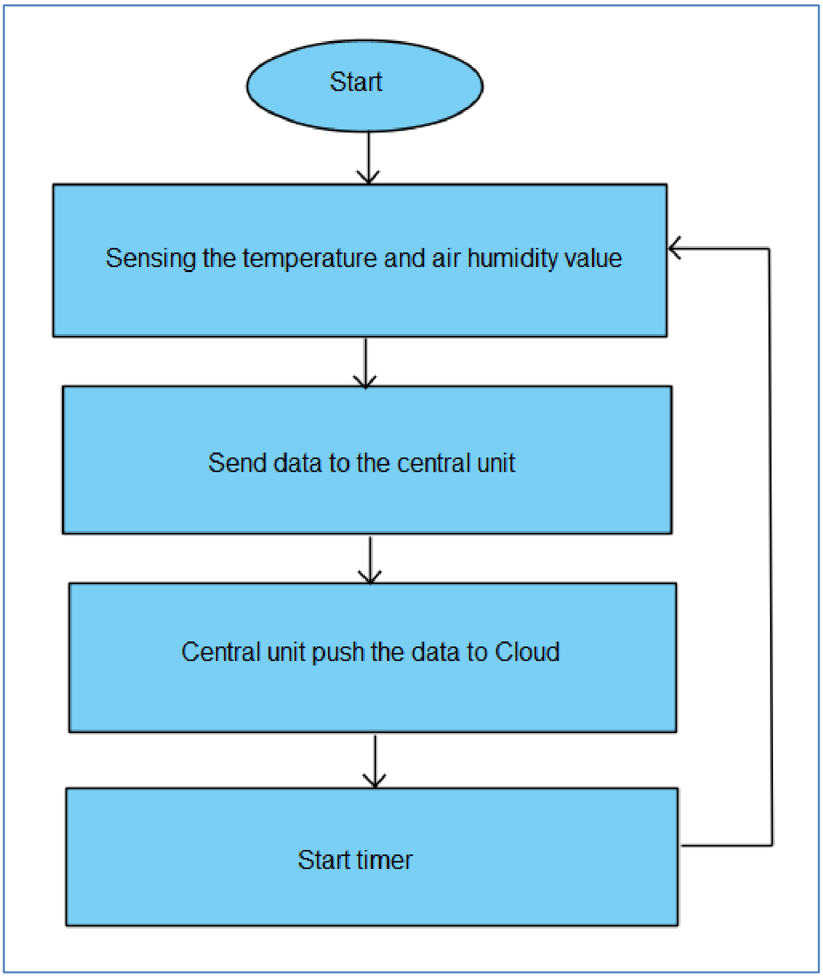


Figure 4-2-1: The flowchart of sensor module.

As shown in Figure 4-2-1, when the system starts to run, the DHT11 sensor will start to sense the humidity and temperature of the environment. When it was done, it will send the data to the Raspberry Pi and start the timer respectively in order to sense the next readings.

4.2.2 The Camera Module

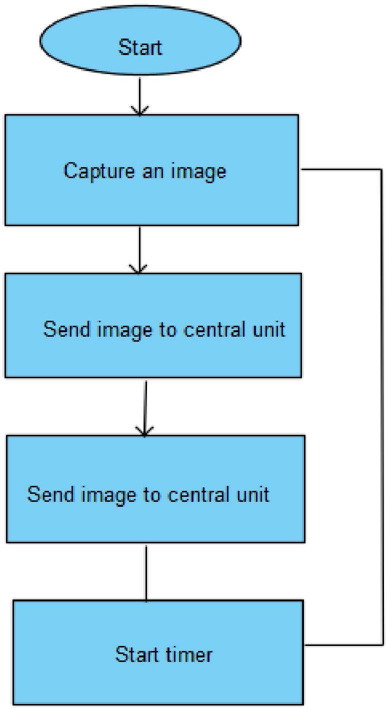


Figure 4-2-2: The flowchart of camera module.

According to Figure 4-2-2, the camera captures an image and sends it back to the Raspberry P. Then it start a timer to initiate the next capture.

4.2.3 The Fan Module

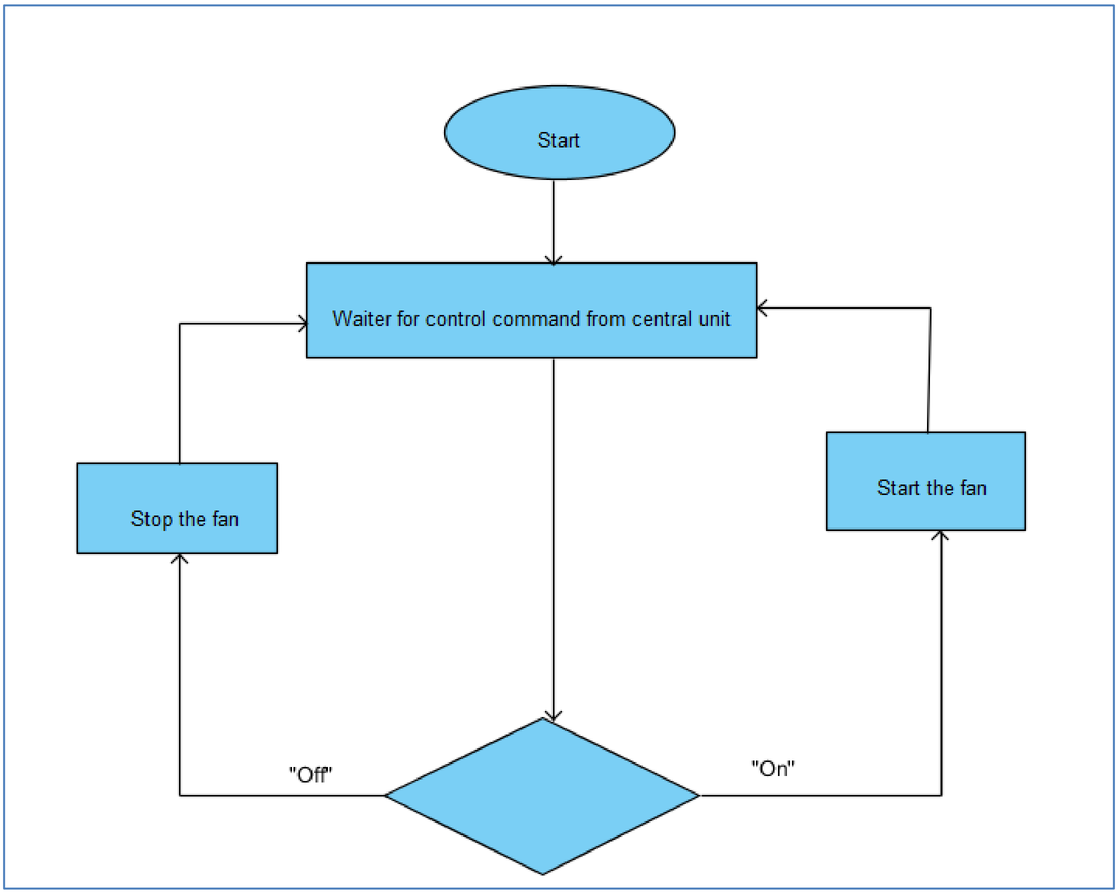


Figure 4-2-3: The flowchart of fan module.

In Figure 4-2-3, the fans are always waiting for the control command of the Raspberry Pi. If the command received is a turn-on-command, the fan start to spin; if the command is turn-off-command, the spinning fan will stop to spin.

4.2.4 The Irrigation Module

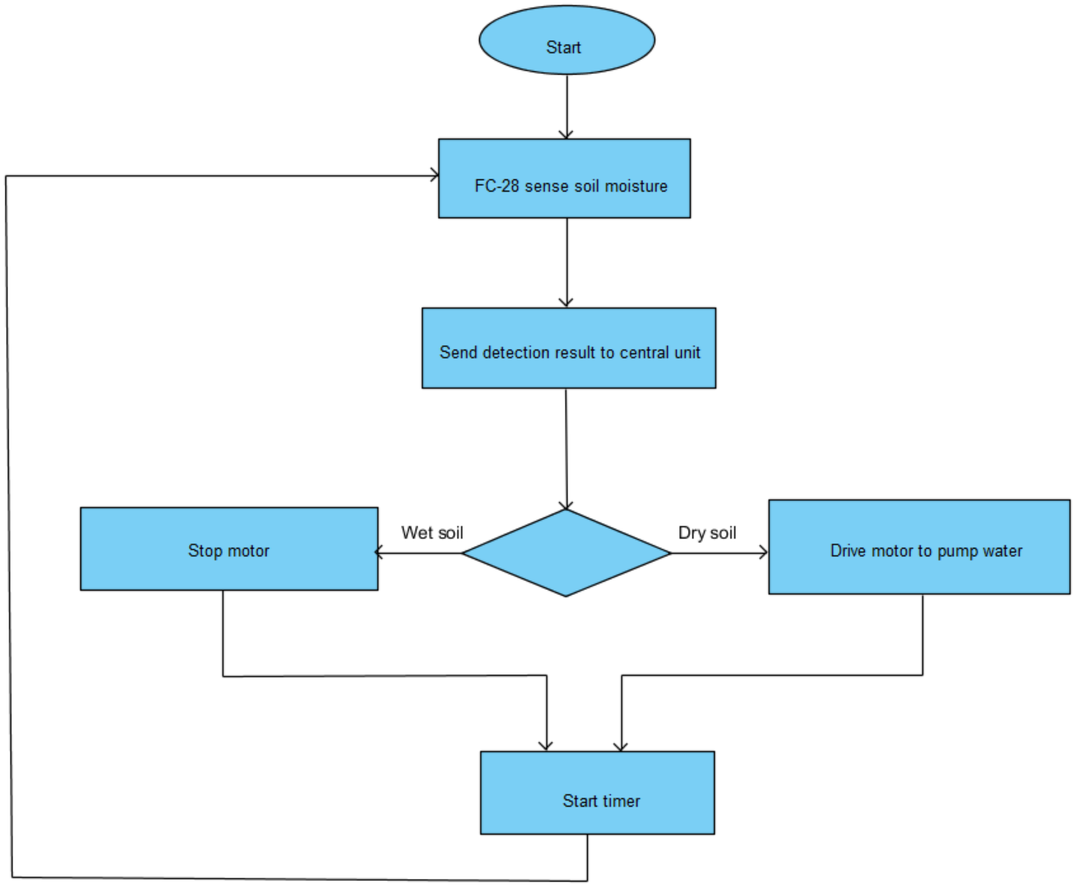


Figure 4-2-4: The flowchart of irrigation module.

As shown in Figure 4-2-4, the FC-28 sensor will firstly try to detect whether the soil is wet or dry. If the soil is dry: the Raspberry Pi will turn-on the water pump to activate the irrigation system; if soil is dry: the Raspberry Pi will stop the water pump. After that, the timer starts to count, and initiates the next moisture detection.

4.3 System Flow

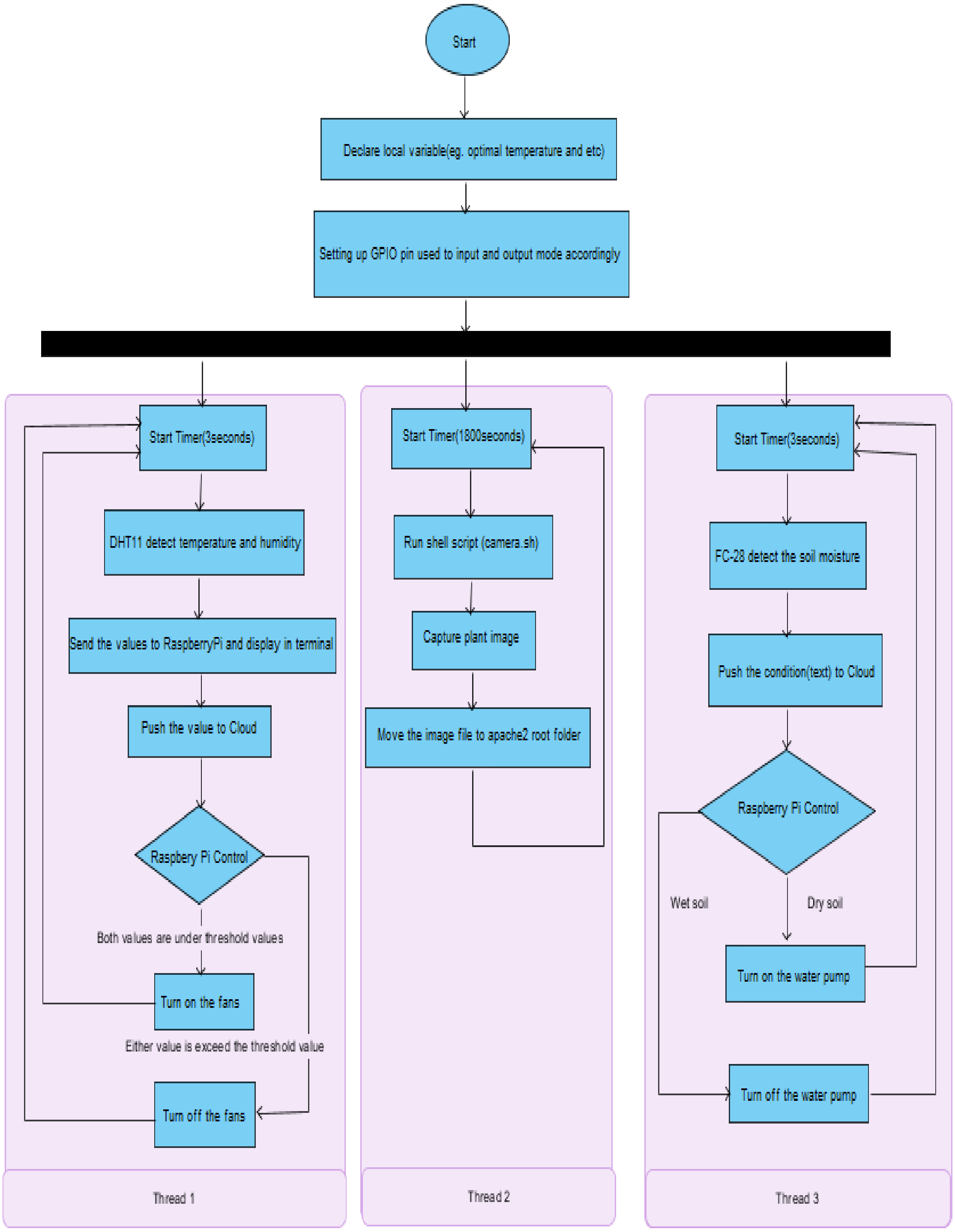


Figure 4-3-1: The flowchart of python program.

The flowchart of the main python program is shown in Figure 4-3-1. The program is running in the Raspberry Pi 2 (RPi). Initially, the RPi will set the pre-defined threshold values for the temperature and humidity. Then, it will set the General-Purpose Input / Output (GPIO) pins of the RPi according to the physical wiring of the sensors, fans and the water pump. After that, the program will create 3 threads for the functions of temperature and humidity sensing, the camera, and irrigation.

For the thread 1 that defined the temperature and humidity sensing, RPi will initially starting a timer of 3seconds, and followed by the detection of temperature and humidity values by the DHT11 sensor. Once the sensor has sent the reading back to the RPi, the RPi will send the data to the Cloud (*dweet.io*) and then determine whether to turn the fans on or off according to the temperature and humidity values if any of these two values have exceeded the predefined threshold values. After that, this thread starts the timer again to continue the iteration of this function.

On the other hand, for the thread 2 that defined the camera function, RPi will start a timer of 30minutes. Once the timer has done count off, the RPi will execute a shell script to capture the plant image. In this script, the image file will then be moved to the apache2 root folder as it will be used to display the image via the web browser within the local network. Lastly, the timer starts again to trigger next camera function.

Lastly, for the thread 3 that defined the irrigation function, RPi will start firstly starting a timer of 3seconds and trigger the FC-28 soil moisture sensor. The sensor will return its detection to RPi in the form of a digital input. Once the RPi has received the digital input, it will send the detection as a description of the soil condition in text to the Cloud. Then RPi will decide to control the water pump whether turn it on to pump to activate the irrigation system or turn it off if the soil is not dry anymore. Finally, this function starts again after the timer has count off.

4.4 GUI Design

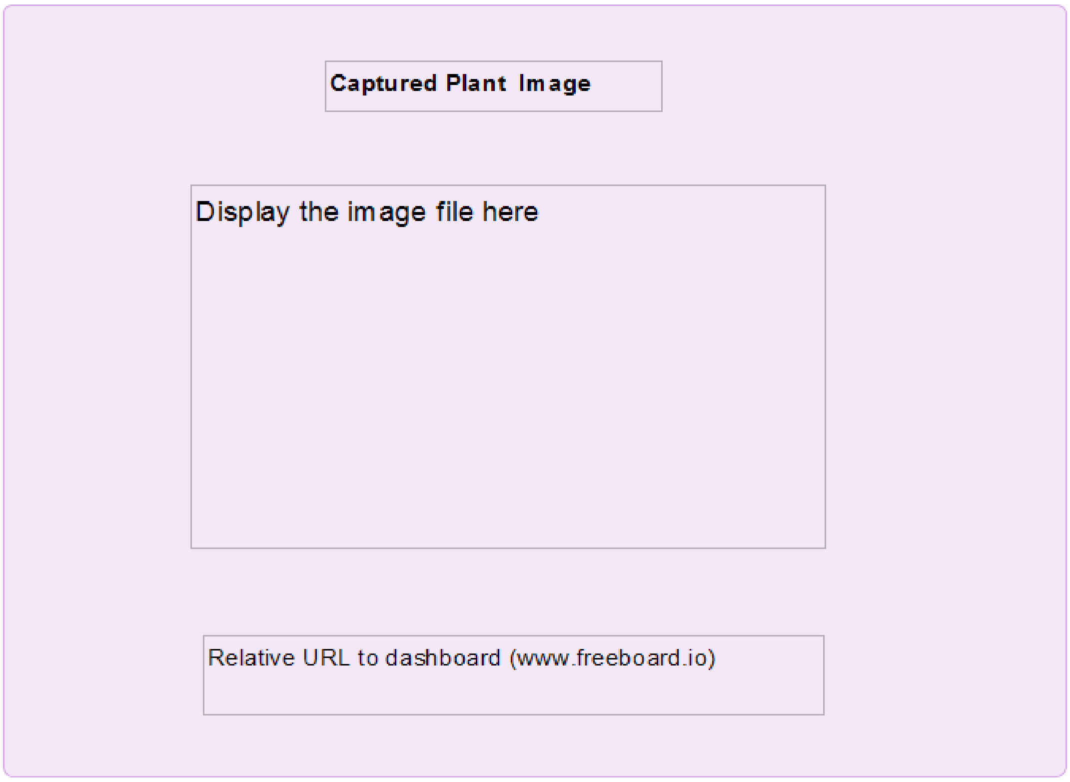


Figure 4-4-1: GUI design of the html file in local web services

Figure 4-4-1 shows the simple HTML file hosted in the apache2 web server. This simple HTML file is used to display the plant image captured by the thread 2 in section 4.3. At the bottom of this HTML file, there is a link point to custom dashboard service provided by *http://www.freeboard.io/*.

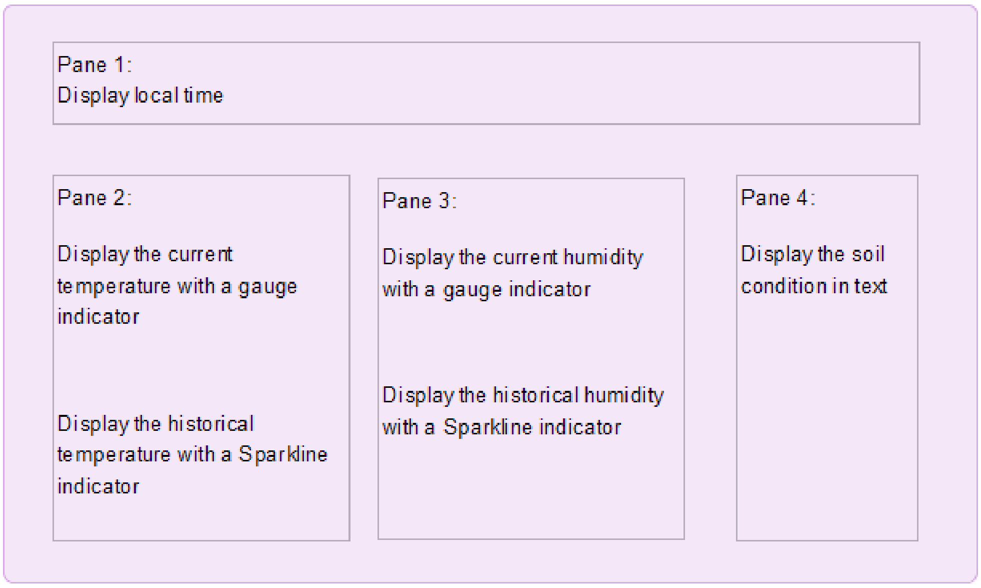


Figure 4-4-2: GUI Design of the dashboard

Figure 4-4-2 shows the GUI design of the custom dashboard. There will be 4 pane in this dashboard to display the local time, the temperature, the humidity and the soil condition. The local time and soil condition are display in text whereas the temperature and humidity are display by using the gauge and sparkline indicator.

4.5 Concluding Remark

In summary, the system architecture with its functional modules are explained in this section 4. The system flow and the GUI Design of html and dashboard are illustrated as well.

Chapter 5: System Implementation

5.1 Hardware Implementation

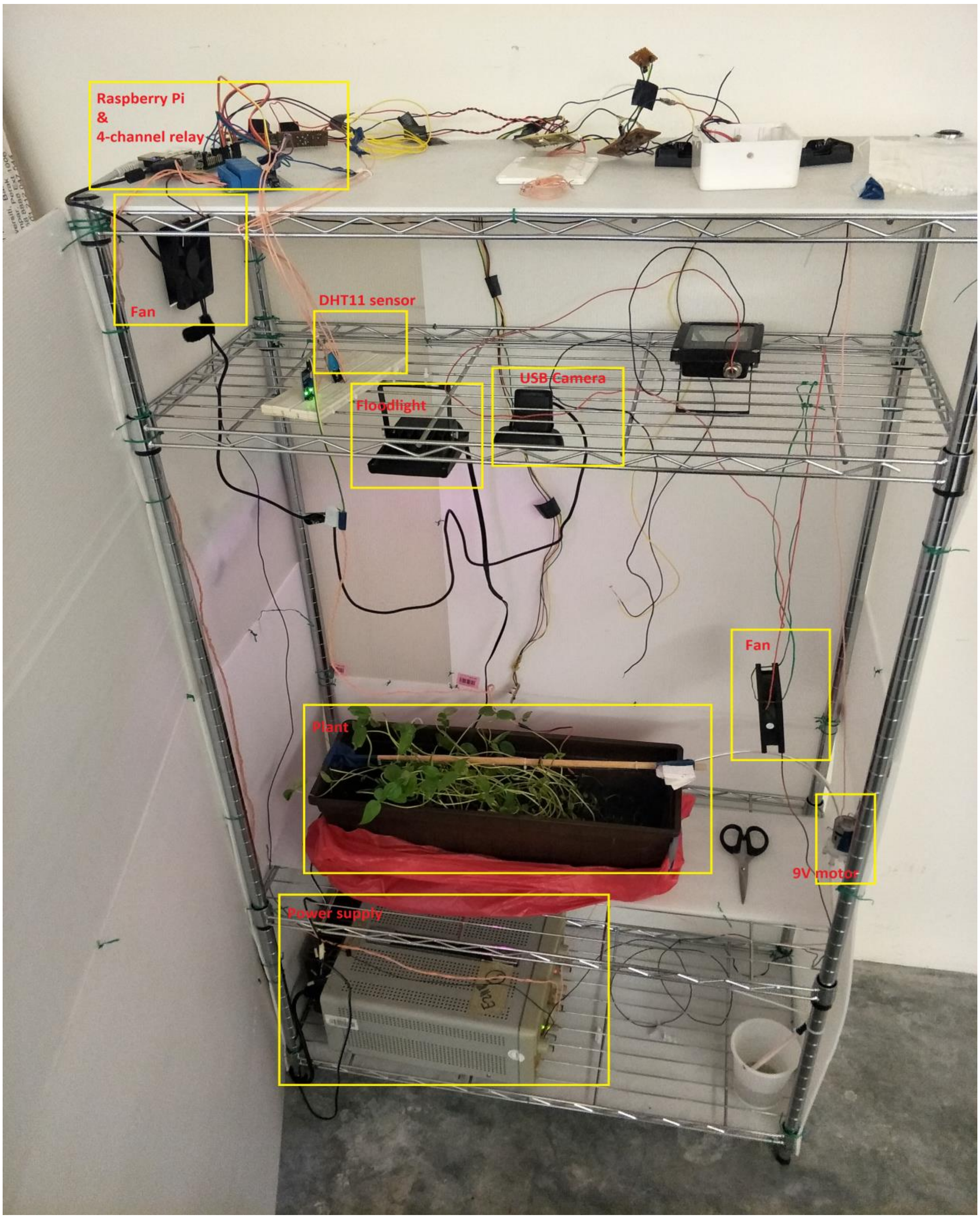


Figure 5-1-1: The system prototype.

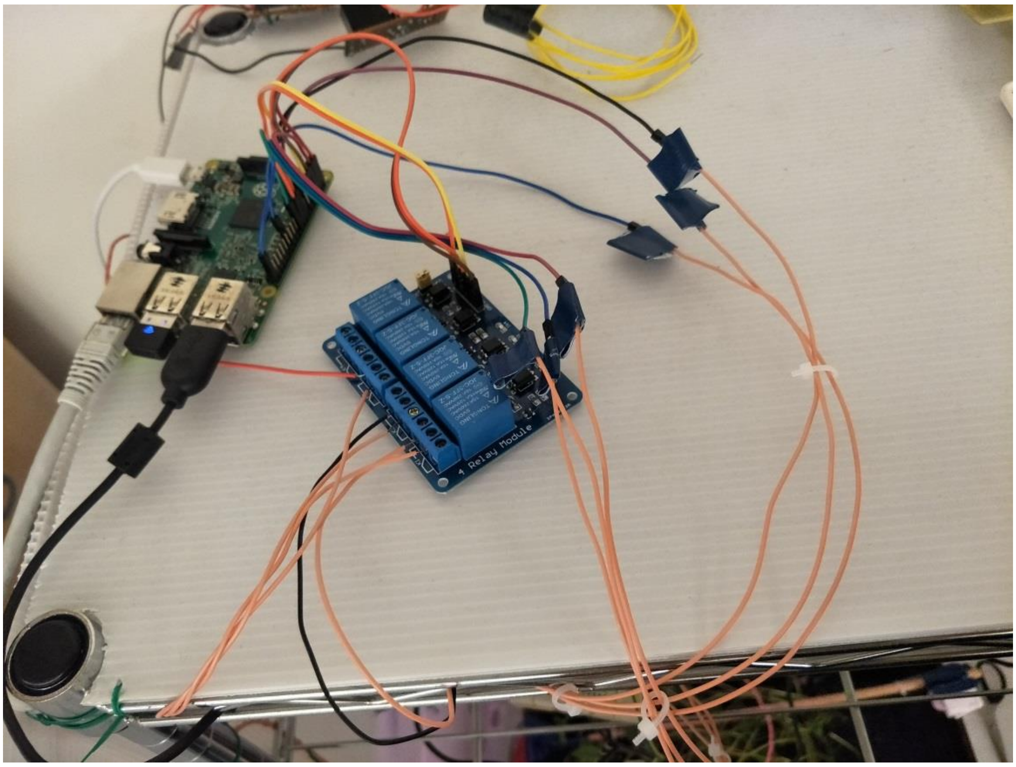


Figure 5-1-2: The RPi and 4-channel relay module.

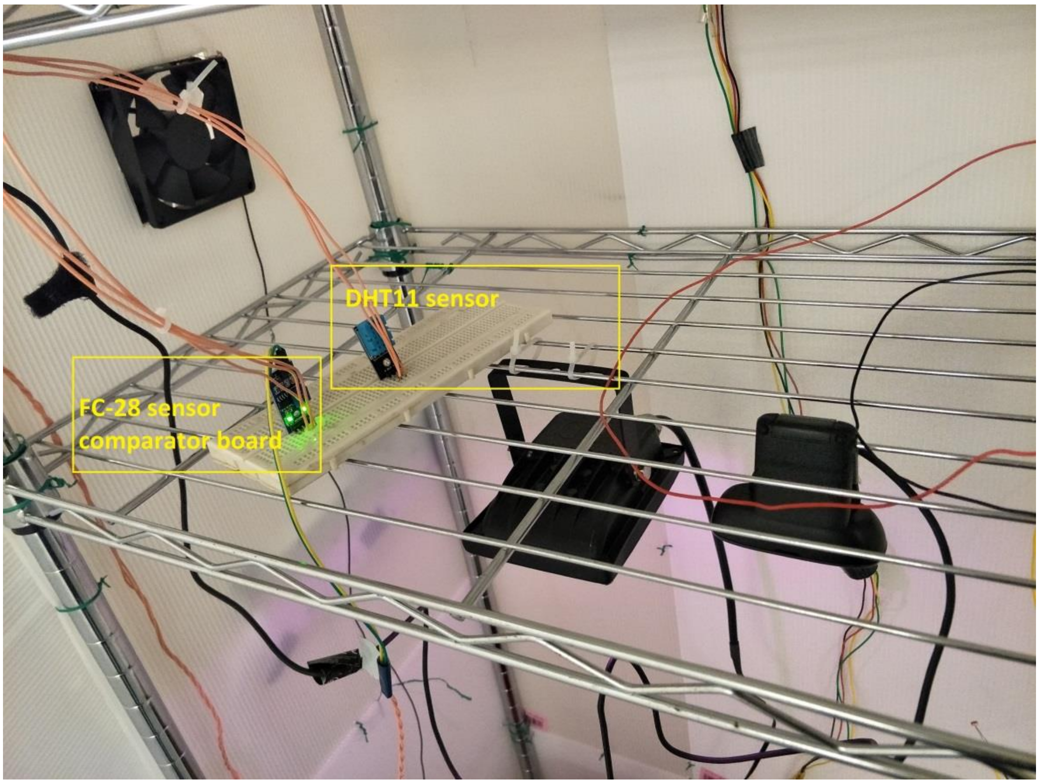


Figure 5-1-3: The DHT11 sensor and FC-28 sensor comparator board.

Figure 5-1-4: The FC-28 soil moisture sensor.

Figure 5-1-5: The 9V motor

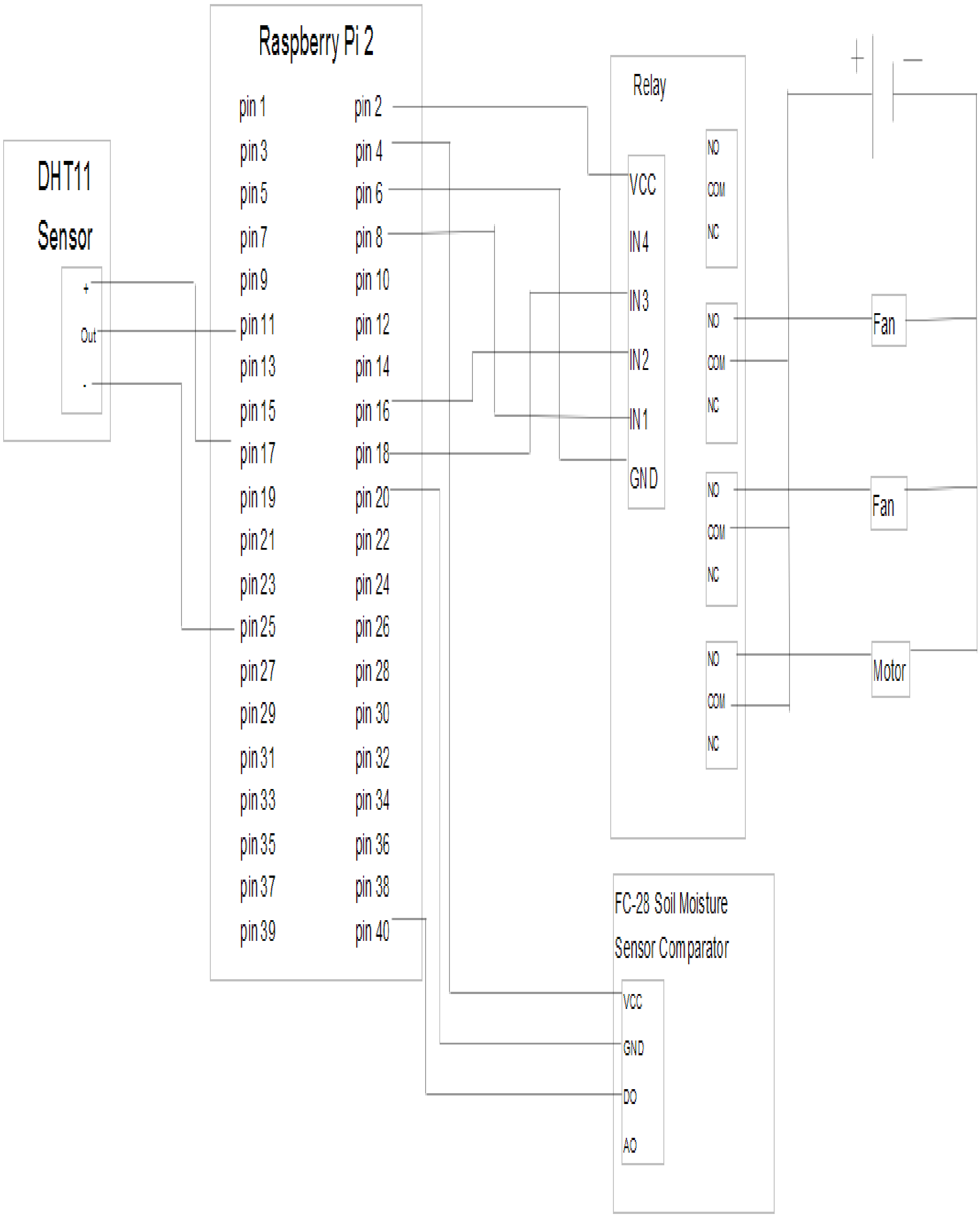


Figure 5-1-6: Raspberry Pi wiring diagram.

Table 5-1-1: Pin connection between RPi, relay and sensor.

Component	Pin	Component	Pin
RPi	11 *(GPIO 17)*	DHT11	Output
	17 *(3.3V)*		Power(+ve)
	25 *(Ground)*		GND(-ve)
	4 *(5V)*	FC-28 Soil Moisture Sensor	VCC
	20 *(Ground)*		GND
	40 *(GPIO 21)*		DO
	2 *(5V)*	Relay	VCC
	6 *(Ground)*		GND
	8 *(GPIO 14)*		IN1
	16 *(GPIO 23)*		IN2
	18 *(GPIO 24)*		IN3

The system prototype is shown in Figure 5-1-1. According to Figure 5-1-6, the RPi is connected to the 4-channel relay and the relay is act as the switch to control the fans and 9V motor. For the relay, the 9V motor is connected to the Normal Open (NO) of channel 1 whereas the two fans are connected to the NO port of channel 2 and channel 3 respectively. The COM port of channel 1, channel 2 and channel 3 are supply with 5V voltage. The relay inputs of these 3 channels are connected to RPi pin 6, pin 16 and pin 18. The channel is switch on when the pin of RPi is sending voltage to the relay input to control the fans and motor.

The DHT11 and FC-28 sensors are connected to the RPi as illustrated in Figure 5-1-6 and in Table 5-1-1. The FC-28 sensor has 2 output type which are digital output (DO) and analogue output (AO). In this system, the DO is used instead of AO as AO will need to use an analogue-digital-converter (ADC) and the ADC is not provided by UTAR.

5.2 Software Implementation

This section will include the steps of installing the software needed in this project.

5.2.1 Install MobaXterm

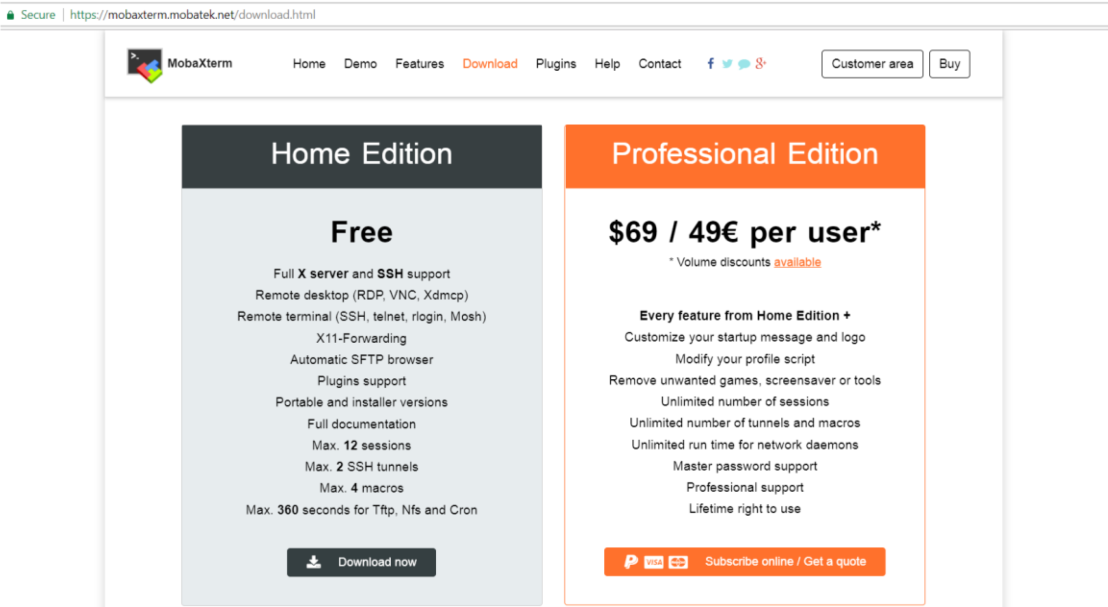


Figure 5-2-1-1: MobaXterm website

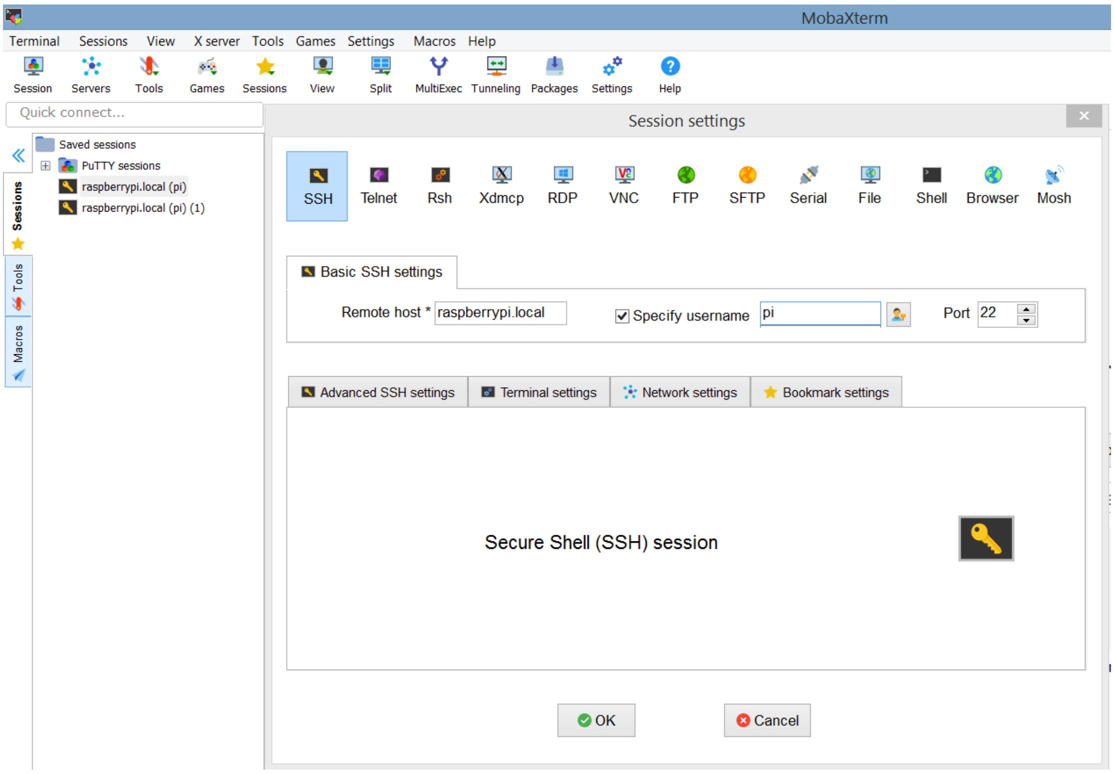


Figure 5-2-1-2: SSH session setup.

MobaXterm is use to connect the Raspberry Pi via a SSH session. Firstly, download the installer from MobaXterm website as shown in Figure 5-2-1-1, then set the SSH session with host = raspberrypi.local, username = pi, port =22 as shown in Figure 5-2-1-2. Then, connect the laptop to the raspberry pi by using a Ethernet cable and chose to start the SSH session created just now and open the user interface by typing "*/etc/X11/Xsession*".

5.2.2 Installing Apache web server

The apache web server is used in this project to display the image files captured by the camera module to the user via the web browser within the local network.

To install apache server, type the following commands in to the Terminal:

- sudo apt-get update
- sudo apt-get upgrade
- sudo apt-get install apache2 –y

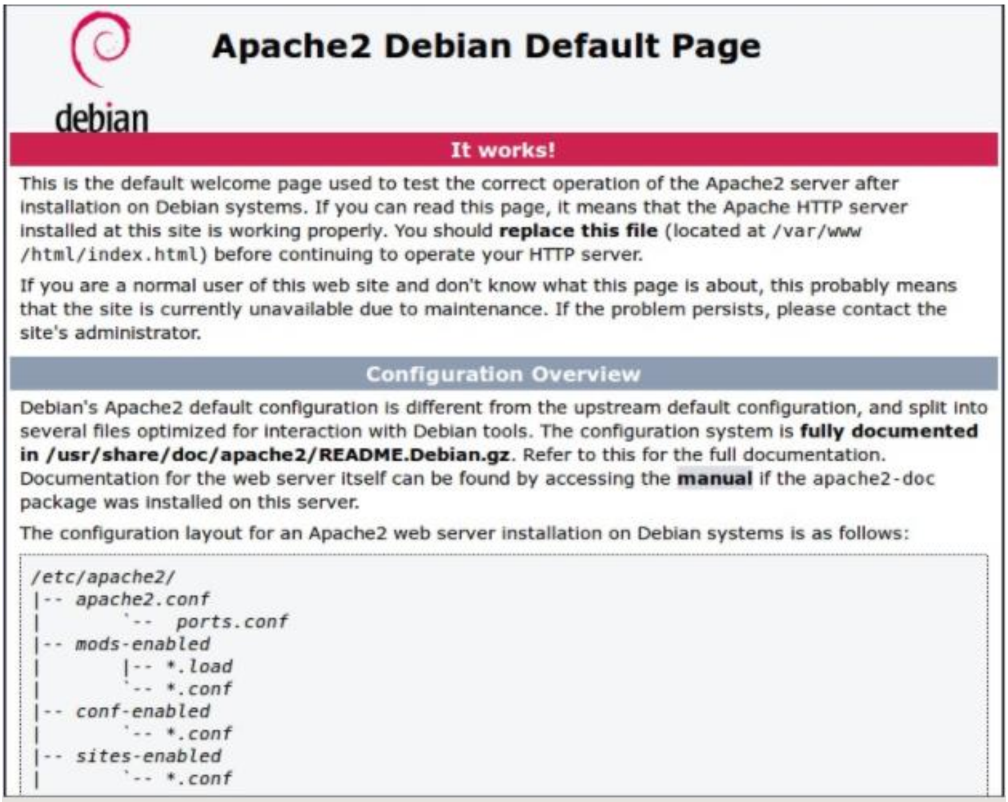


Figure 5-2-2-1: Testing apache web server.

After installation is done, type in "*http://localhost/*" in the browser in Pi itself or "*http://<ip address of Pi>*" to test the apache web server is functioning and you should see the html page as shown in Figure 5-2-2-1. In Terminal, type in *"cd /var/www/html"* to move the directory to the apache root folder and "*sudo nano index.html*" to edit the html content.

5.2.3 Installing Screen

In order to let the python program runs continuously after disconnect the SSH connection between the Raspberry Pi and the monitor, a program called "screen" is used. This program is able to run the program as the background process so that the program is still running after SSH connection is break as long as the Raspberry Pi is powered. To install it, type *apt-get install screen* and type *screen bash* after it is done installed. Then, it will open another terminal instance and run the python program here. After that, press *CTRL + A +D* to detach the terminal session and *screen –r* to view reconnect to the instance.

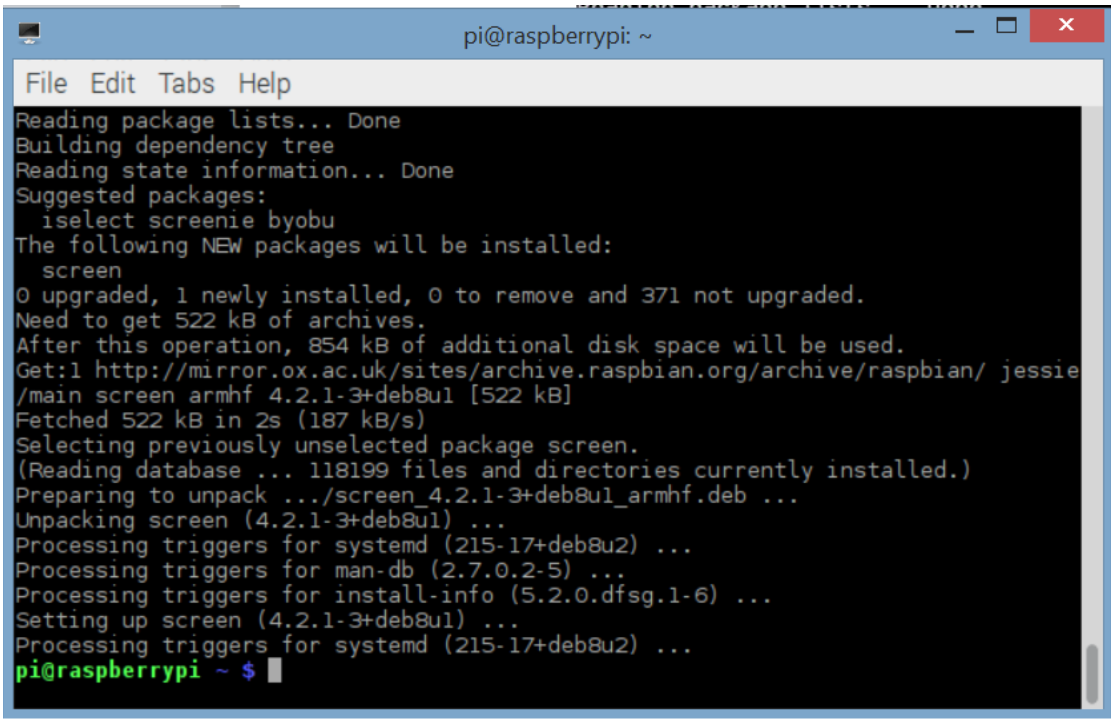


Figure 5-2-3-1: Screen is installed successfully.

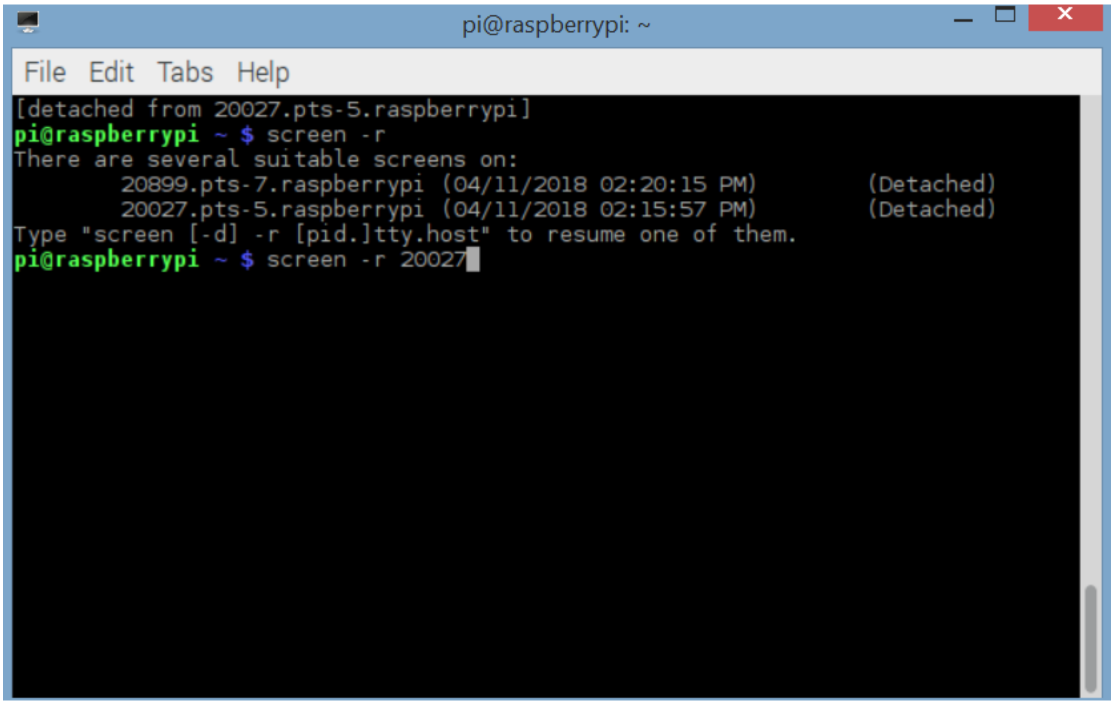


Figure 5-2-3-2: Reconnect to screen instance.

5.2.4 Installing fswebcam

The fswebcam module allow user in suing a standard USB camera to take pictures or video on the Raspberry Pi. To install the fswebcam package, type in the "*sudo apt-get install fswebcam*" in Terminal:

5.3 Setting and Configuration

This section elaborates the steps in setting up of the system. Among the steps, we need to create the main python program and a shell script to use fswebcam, edit the html content and customize the dashboard to display the data.

5.3.1 Python program

In Raspberry Pi, create a new text file and add the content as shown in Figure5-3-1-1, Figure 5-3-1-2 and Figure 5-3-1-3. Then, save the file with name "*fyprun.py*". The python program declares some local variables, setting up the GPIO Pin, define and execute the thread and send the values of variable Temperature and Humidity to the object named "*chongfyp1*" in the Cloud

```python
import RPi.GPIO as GPIO
import sys
import dweepy
import time
import Adafruit_DHT
import subprocess
import pigpio
from threading import Thread

#GPIO number
GPIO.cleanup()
fan_pinA = 24
fan_pinB = 23
motor_pin = 14
soilSensor_pin = 20
Hsensor_pin = 17  #pin11=gpio17
optTemp = 30      #For green bean
optHumd = 80      #For green bean
msg1 = "The soil is dry"
msg2 = "The soil is wet"
option = True

GPIO.setmode(GPIO.BCM)
GPIO.setup(fan_pinA, GPIO.OUT)
GPIO.setup(fan_pinB, GPIO.OUT)
GPIO.setup(motor_pin, GPIO.OUT)
GPIO.setup(soilSensor_pin, GPIO.IN)
GPIO.output(fan_pinA, True)#False is on
GPIO.output(fan_pinB, True) #False is on
GPIO.setup(motor_pin, False)#False is on

#Define thread functions
def fan():
    while True:
        global option
        time.sleep(3)
        print("")
        print("Trying to read the temperature and humidity values....")
        time.sleep(5)
        humidity, temperature = Adafruit_DHT.read_retry(11,Hsensor_pin)
        print("Temperature = %.2f C" %temperature)
        print 'Humidity: {0:0.1f} %'.format(humidity)
        print("")
        print("Try to push these 2 values to Cloud...")
        if option == True:
            dweepy.dweet_for('chongfyp1',{'Temperature':str(temperature), 'Humidity':str(humidity), 'Soil':str(msg1)})
        else:
            dweepy.dweet_for('chongfyp1',{'Temperature':str(temperature), 'Humidity':str(humidity), 'Soil':str(msg2)})
```

Figure 5-3-1-1: Python program content page 1.

```
            dweepy.dweet_for('chongrypi',{'Temperature':str(temperature), 'Humidity':str(humidity), 'Soil':str(msg2)})
        if temperature > optTemp or humidity > optHumd:
            print("Temperature or Humidity is too high")
            print("Fans are turned ON")
            GPIO.output(fan_pinA, False)
            GPIO.output(fan_pinB, False)
        else:
            print("Temperature or Humidity is under optimal values")
            print("Fans are turned OFF")
            GPIO.output(fan_pinA, True)
            GPIO.output(fan_pinB, True)

def camera():
    while True:
        time.sleep(30)
        print("")
        print "Camera start"
        subprocess.call("./camera.sh", shell=True)
        print "Camera end"
        print("")

def waterPump(soilSensor_pin):
    while True:
        time.sleep(3)
        print("")
        if GPIO.input(soilSensor_pin):
            print(msg1)
            global option
            option= True
            try:
                print("Starting the water pump now")
                GPIO.output(motor_pin, False) # motor on when false
                print "on"
            except KeyboardInterrupt:
                GPIO.cleanup()
                exit()
        else:
            print(msg2)
            global option
```

Figure 5-3-1-2: Python program content page 2.

```
        else:
            print(msg2)
            global option
            option = False
            try:
                print("Ending the water pump now")
                GPIO.output(motor_pin, True) # motor off when true
                print "Off"
            except KeyboardInterrupt:
                    GPIO.cleanup()
                    exit()
        print("")

Tfan = Thread(target=fan)
Tcamera = Thread(target=camera)
Twater = Thread(target=waterPump)
Tfan.daemon = True
Tcamera.daemon = True
Twater.daemon = True
Tfan.start()
Tcamera.start()
Twater.start()

GPIO.add_event_detect(soilSensor_pin, GPIO.BOTH, bouncetime=300)
GPIO.add_event_callback(soilSensor_pin, waterPump)

#/dweet/for/{thing}
#thing -> chongfyp1

while True:
    try:

    except KeyboardInterrupt:
        GPIO.cleanup()
        exit()
```

Figure 5-3-1-3: Python program content page 3.

5.3.2 HTML content

At directory “*/var/www/html*”, typing “*sudo nano index.html*” to edit the html content by replacing the <body> section as shown in Figure 5-3-2-1.

```
<body>

    <div>
        <h2>The Plant Image</h2>
        <img src="image1.jpg" alt="Plant Image" width="700" height="700">
    </div>

    <div>
        <a href="https://freeboard.io/login">Go to Freeboard.io</a>
    </div>

</body>
```

Figure 5-3-2-1: HTML content.

5.3.3 Dashboard customization

The Freeboard.io provides a platform to create a dynamic dashboard for the IoT application. Firstly, sign up for a account at *https://freeboard.io/account*. Secondly, login with the account and create a new dashboard. Then, add a data source name “*FYP system*” with thing name “*chongfyp1*” as shown in Figure 5-3-3-1. After that, add 6 pane to display the temperature, humidity, soil condition description and time respectively as shown in Figure 5-3-3-2 to Figure 5-3-3-8.

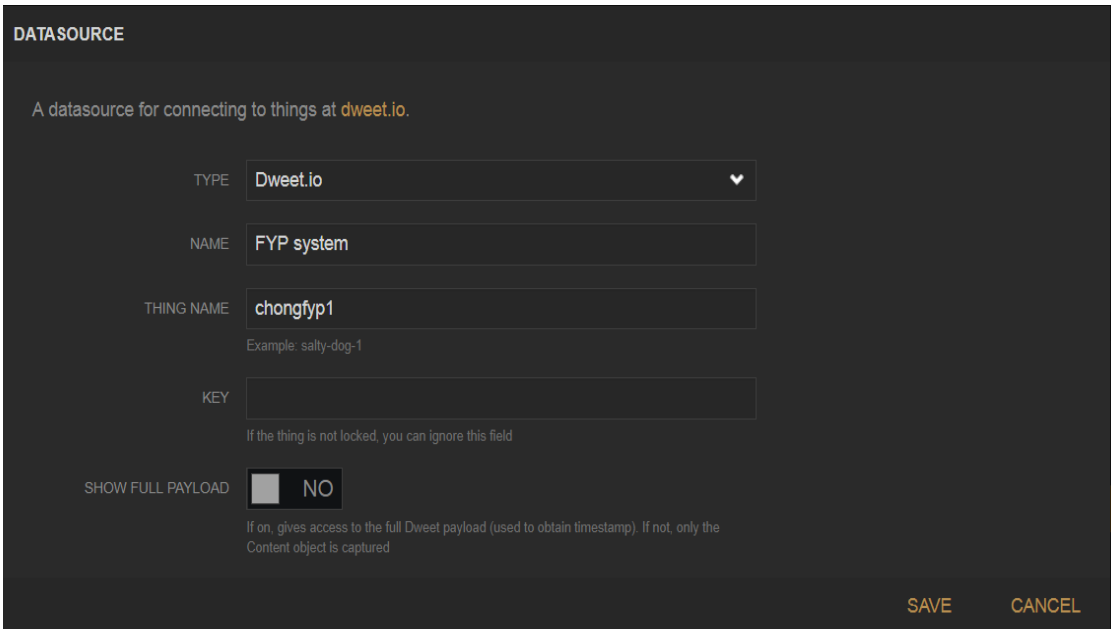


Figure 5-3-3-1: Data source 1 for Dashboard

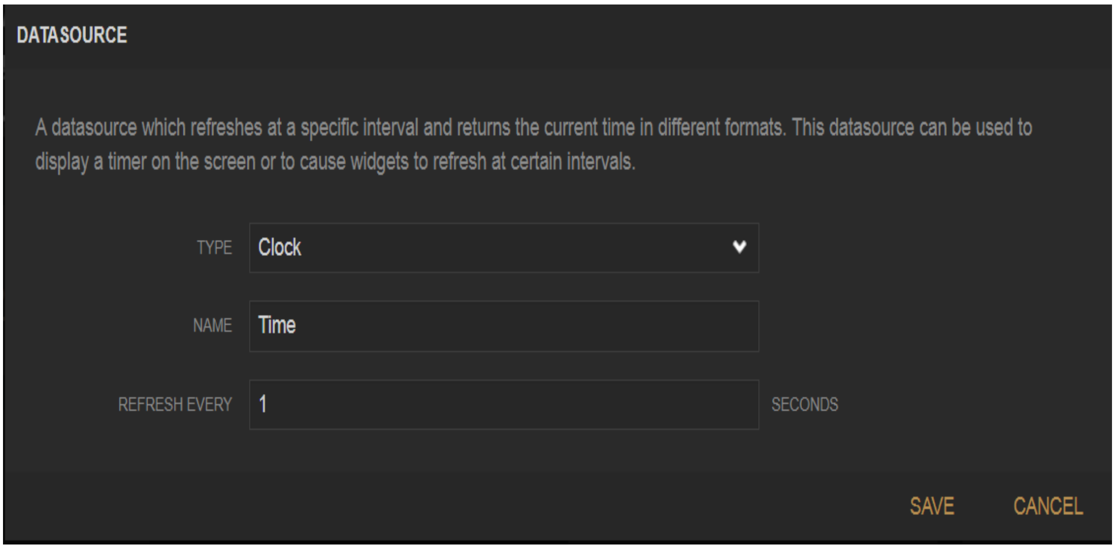


Figure 5-3-3-2: Data source 2 for Dashboard

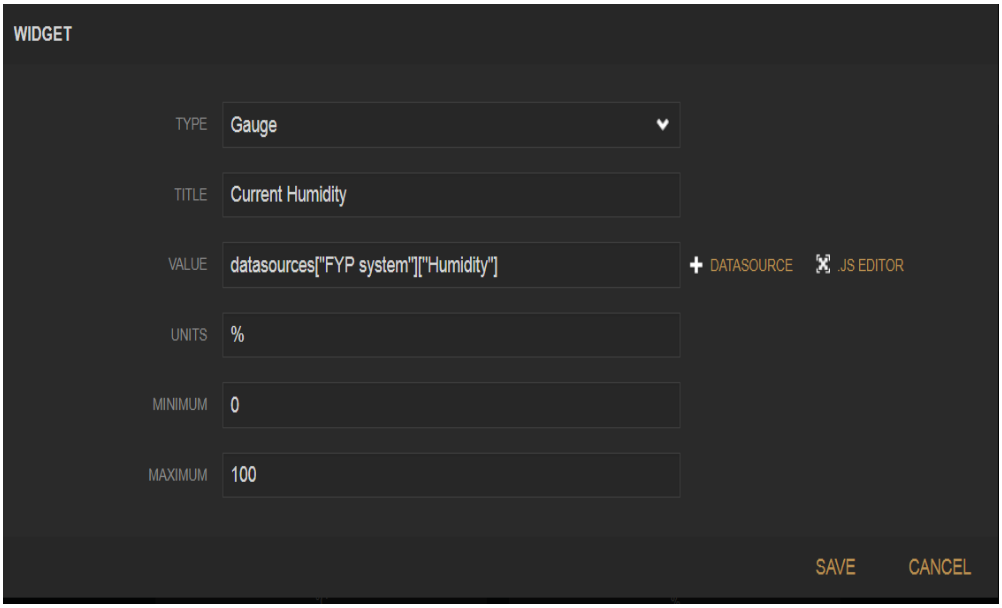


Figure 5-3-3-3: Dashboard pane for Humidity.

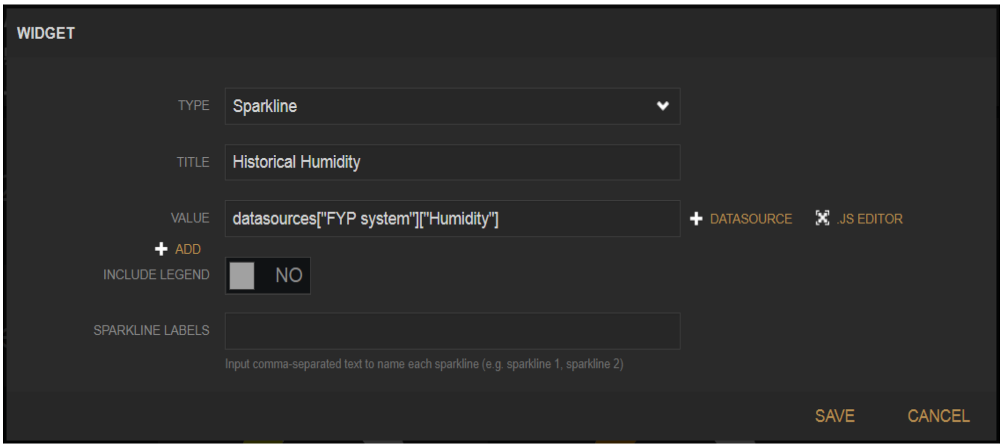


Figure 5-3-3-4: Dashboard pane for Humidity trend.

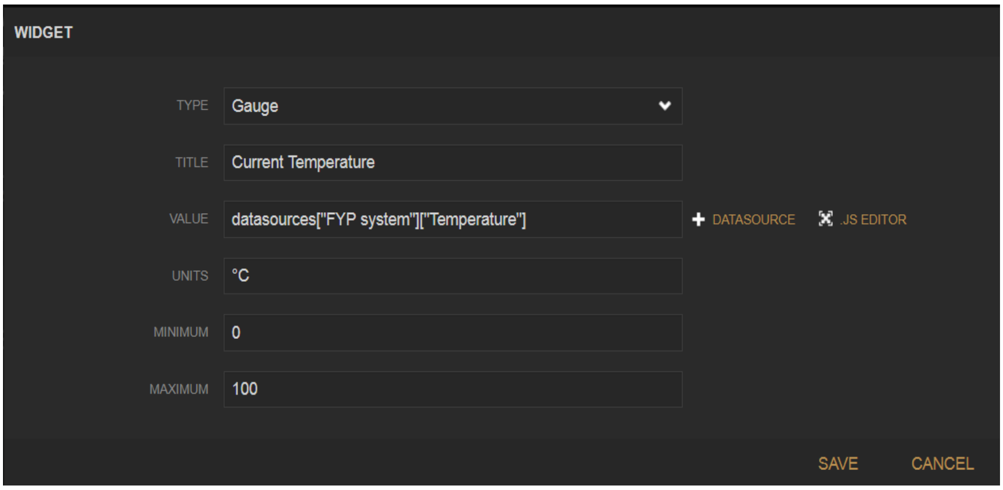


Figure 5-3-3-5: Dashboard pane for Temperature.

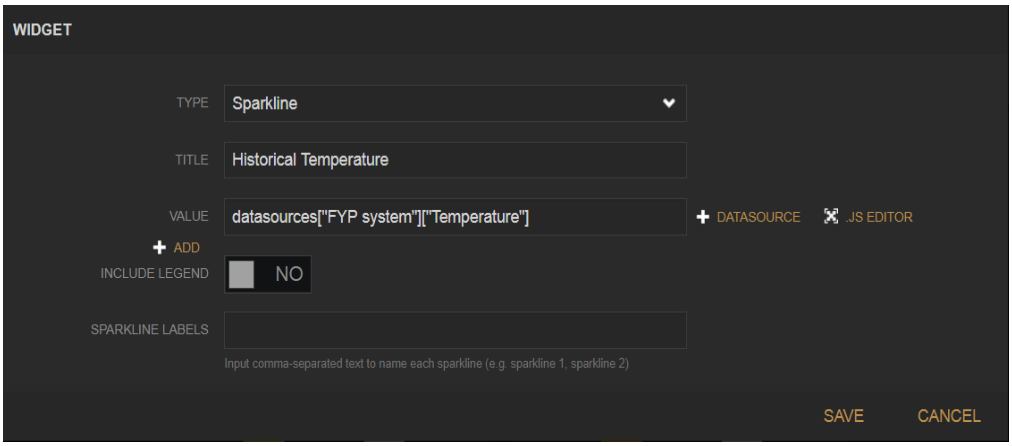


Figure 5-3-3-6: Dashboard pane for Temperature trend.

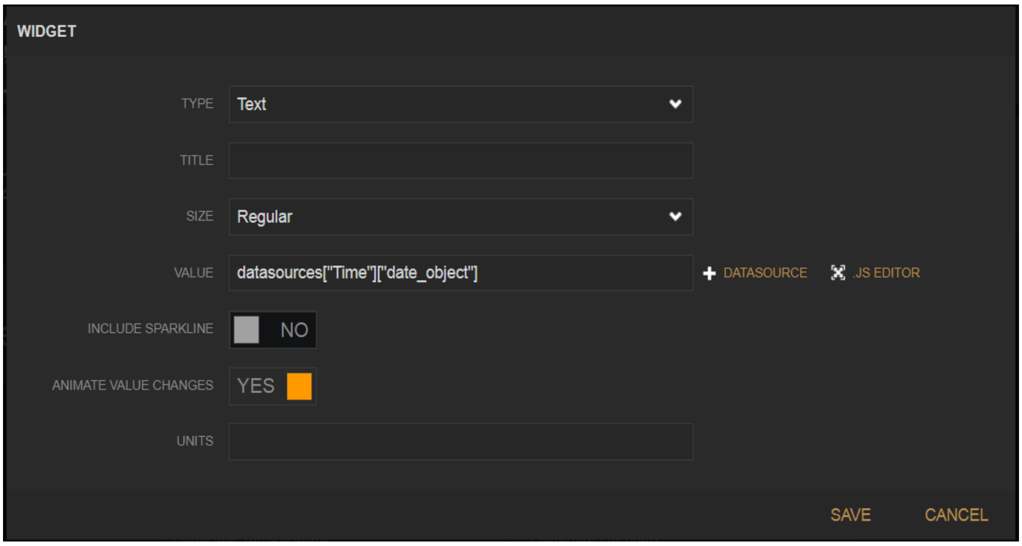


Figure 5-3-3-7: Dashboard pane for Time.

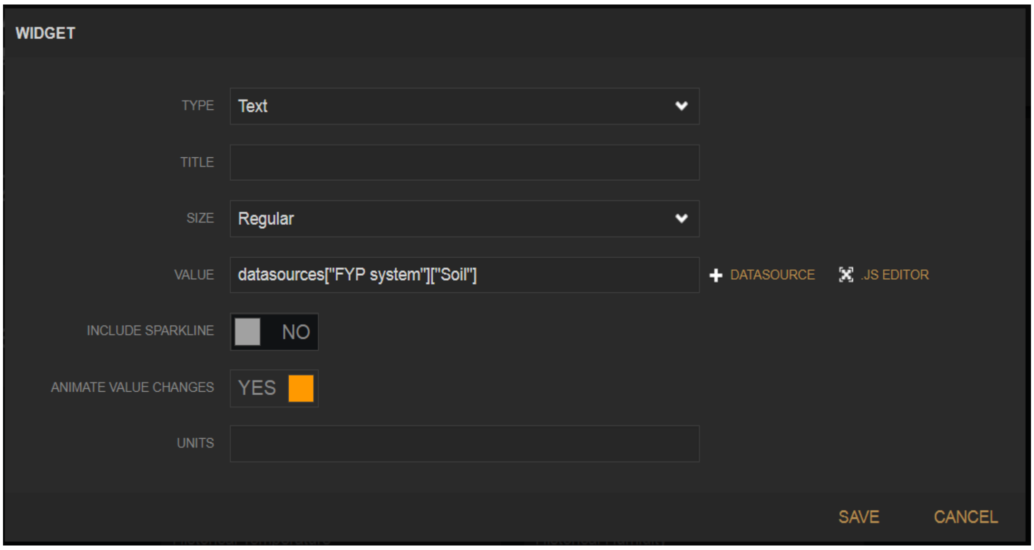


Figure 5-3-3-8: Dashboard pane for soil condition.

5.3.4 Others

Besides from creating the python program, we still need to create a shell script to execute the fswebcam command in order to use the USB camera. Now, create another text file named "*camera.sh*" and add the content as shown in Figure 5-3-4-1. This script will call the fswebcam to capture a image and save as "*image1.jpg*" and move it to the apache root folder. Furthermore, we have to check is there any other process is using the USB camera to ensure the camera functionality by type in "*ps -A*" to check all process. After that found that there is another application called “motion” is utilizing the camera thus we have to kill the process. In this case, the motion process id is 691 and we kill the process by command “*sudo kill –SIGTERM 691*” as shown in Figure 5-3-4-3.

```
fswebcam image1.jpg
sudo mv /home/pi/image1.jpg /var/www/html/image1.jpg
```

Figure 5-3-4-1: Shell script camera.sh

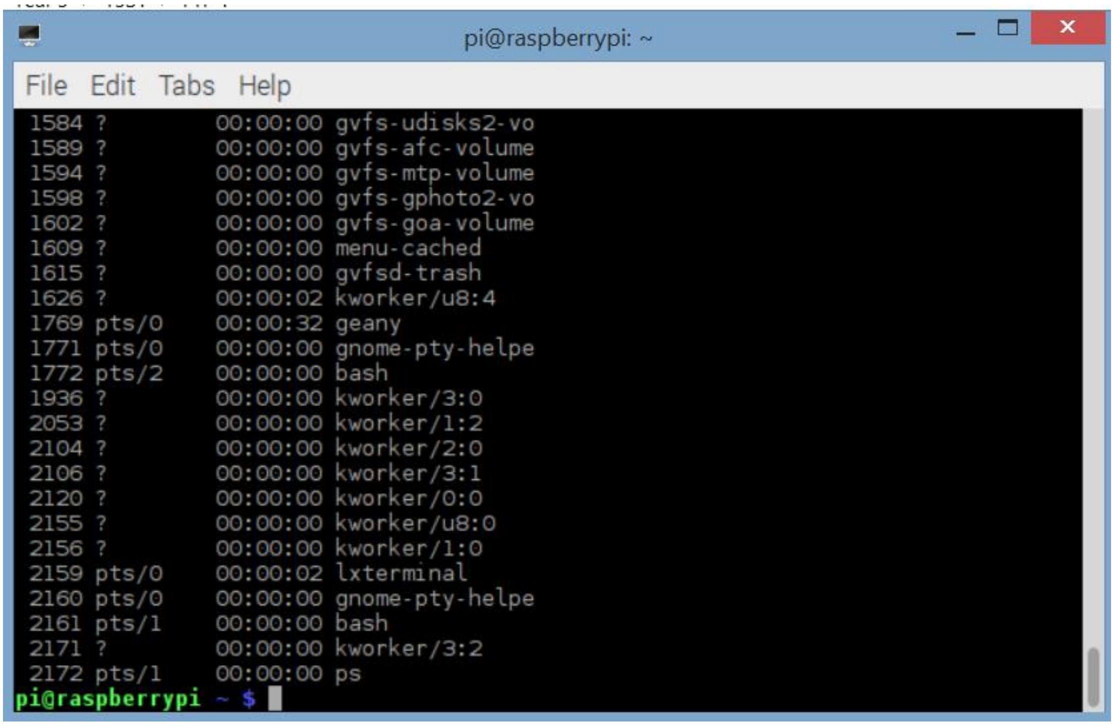


Figure 5-3-4-2: Process list

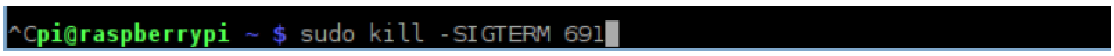


Figure 5-3-4-3: Kill unwanted process.

5.4 System Operation

The Figure 5-4-1 and Figure 5-4-2 show the running Python program in Terminal. In both case, I have set a different threshold value to determine the functionality of the sensor and fan modules. In case of the temperature or humidity value is lower than the threshold value, the fans are off; else the fans will be triggered to turn.

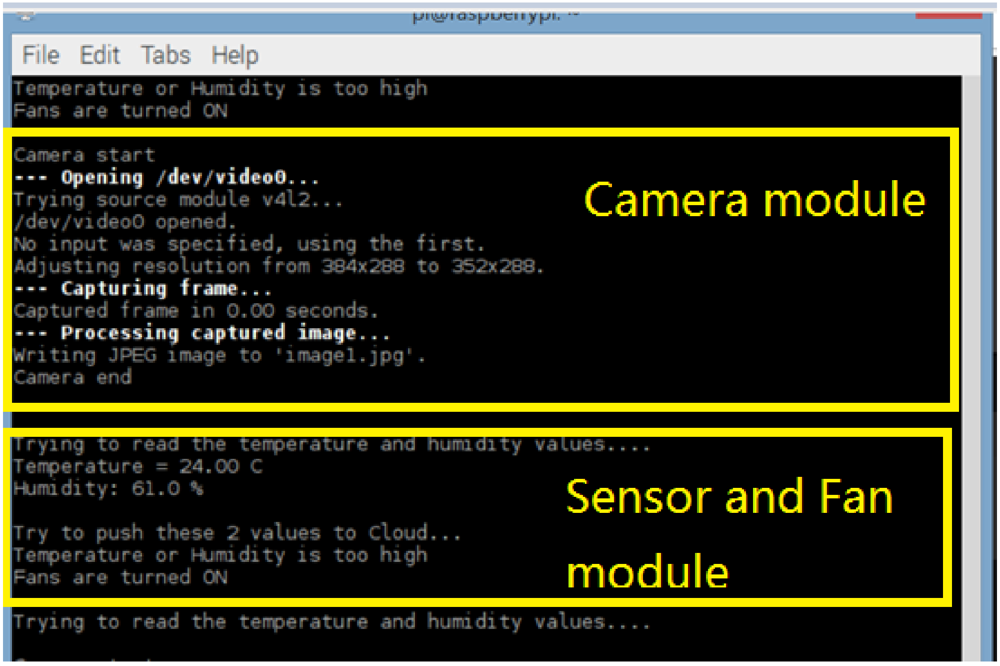


Figure 5-4-1: The running program in Terminal.

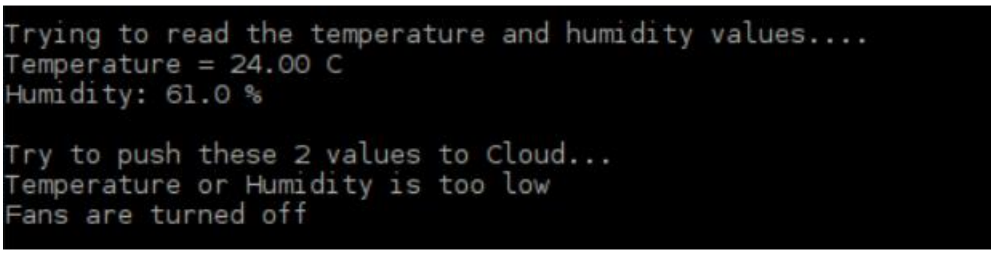


Figure 5-4-2: Sensor and Fan modules in Terminal.

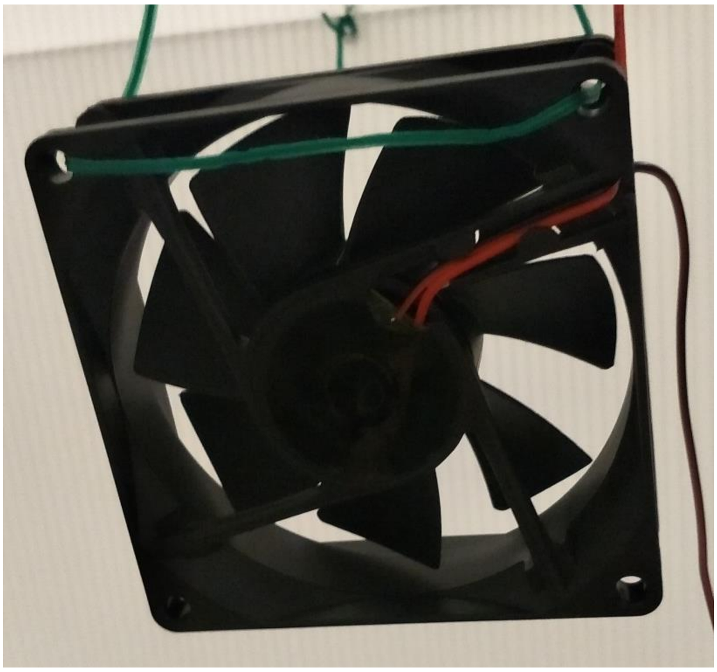


Figure 5-4-3: Fan switched-off.

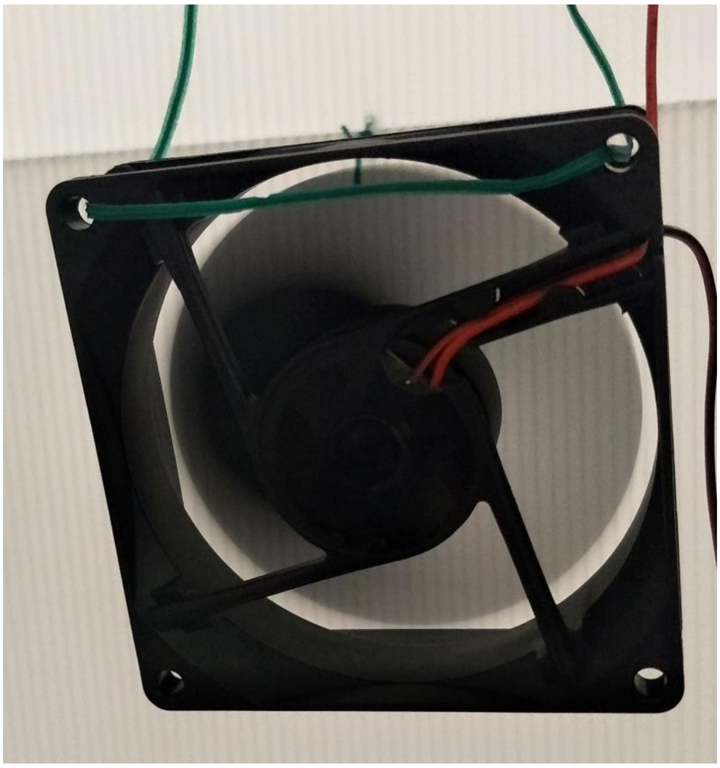


Figure 5-4-4: Fan switched-on.

Figure 5-4-5: Irrigation switched-on.

The FC-28 soil moisture sensor is detecting the soil condition. In Figure 5-4-5, the sensor detected the soil is dry and triggered the motor to pump the water. Then the water is pumped to the pipe and watering the plant.

Figure 5-4-6: Web hosted in local Apache web server.

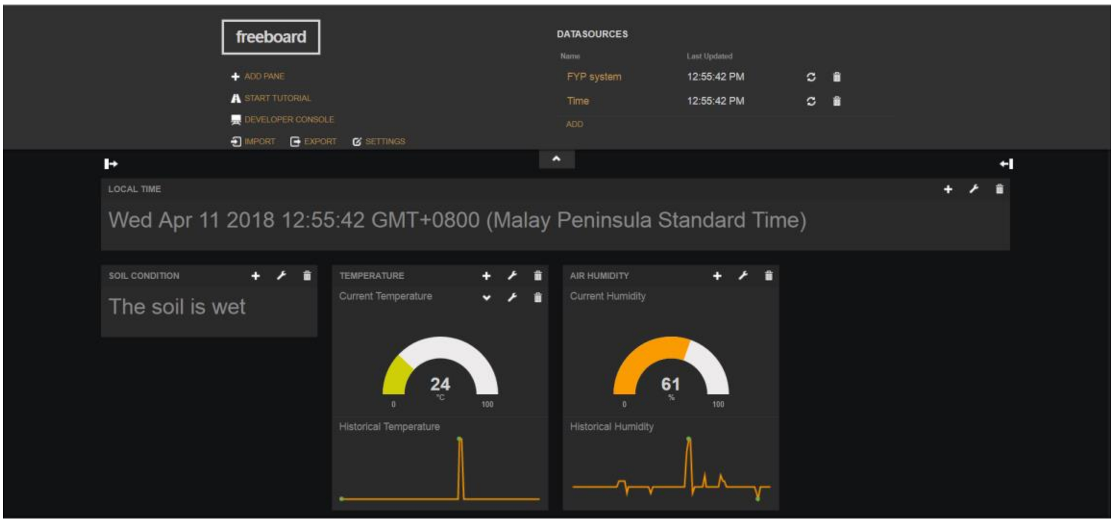


Figure 5-4-7: The Dashboard.

The plant image captured by the USB camera is display in the web page hosted in local apache web server as shown in Figure 5-4-6. And, the link in bottom will redirect to the dashboard shown in Figure 5-4-7

5.5 Concluding Remarks

In summary, all the hardware and software implementations are explained section 5. Moreover, the system operation is shown as well which includes the physical system and the display mechanisms of data.

Chapter 6: System Evaluation and Discussion

6.1 System Testing and Evaluation

The system is tested by growing the bean-sprout and pak choi. According to Limwiwattana, Tongkhao and Na Jom (2015), the optimal growing temperature of bean sprout is 35 °C and relative humidity of 80%. On the other hand, according to Quickcrop.co.uk.(n.d.), pak choi is a cool-weather plant which grows in temperature ranging from 45°F to 75 °F (about 7.22°C to 23.89°C).Thus the pre-defined threshold value for temperature and humidity will be 24 °C and 80%.

During the system testing, the temperature and humidity recorded is around 24°C and 61%. In other words, the room temperature of 24 is below the threshold value of temperature but the threshold value of humidity exceeds the threshold value of humidity. Thus, this has triggered the fans to spin. Ideally, the air circulation generated by the fans should be able to reduce the temperature and humidity level. However, no significant impact is observed in reducing the humidity level. The reason might most probably due to few reasons. For example, the space for farming area is relatively too big for the fans to generate strong air circulation or might due to the locations of fans installation are not able to generate a strong circulation direction.

On the other hand, the FC-28 soil moisture sensor is able to detect the moisture in the soil can able to activate and deactivate the motor to pump the water in irrigation system. However there is a challenge in ensuring the irrigation system can water the whole farming pot or container evenly.

The camera function is working fine and display the image to user by using a web page whereas the dashboard is displaying the current and historical temperature and humidity readings with other information such as the local time and soil condition.

6.2 Objective Evaluation

As we glance back the objectives of this project, the system built in this project has achieved some of them as described below:

- The system has established an indoor farming environment.
- The system provided the real-time monitoring system on crops and farming environment parameter such as the temperature, humidity and soil moisture.
- The system established a simple user interface for the users to view the data via the local web server and dashboard service provided by Freeboard.io.
- The system provided an automatic irrigation system.
- The system may help to reduce the labour daily duty as some of the work has been made automated.

To conclude, the system has achieved 5 objectives out of 6.

6.3 SWOT

Strength	Weakness
• The system controls the sensors, fans, water pump, camera automatically to perform the monitoring and control on indoor farming. • User can view the reading easily via Internet. • The dashboard enables the real-time monitoring on indoor farming.	• The temperature and humidity control performance is not significant. • The irrigation system facing challenge to perform perfect and evenly watering on soil.
Opportunity	**Threat**
• Indoor farming is still new in Malaysia. • Automated process is hoped to increase the work efficiency and effectiveness. • Automated process is hoped to reduce much labour cost. • Indoor farming environment seems easier to be maintained thus suitable in growing rare plant or the plants that facing extinction problems	• Productivity of indoor farming might less than traditional farming under the perfect situation because large indoor space is not common. • Reduce in labour cost but increase in utility cost such as for the 7/24 electricity supply.

Chapter 7: Conclusion and Recommendation

7.1 Conclusion

As the global food demand is rising, the food security has become a popular issue. The traditional agriculture might have some flaws during the agriculture activities, such as the weather is uncontrollable and led the loss of optimal growing environment for the crops and plants, the agriculture activities mostly depend on the farmer's experiences, a large number of labour is employed but efficiency and productivity is not guaranteed. Thus, this project proposed the title "IoT on indoor farming". There are some existing related systems, but most of them are emphasize on the data monitoring. As compared, this project applies the concept of precious agriculture, by using sensors, the environment parameter is monitored. As the enhancement, this project proposed some automation processes such as to control the air temperature and humidity by air circulation generated by the implemented fans. At the same time, the monitored results will be sending to the Cloud and provides a channel for the user to view the real-time data. This indoor farming system also implemented the camera, irrigation module and is expected to implement other possible useful function in future in order to achieve the project objectives.

7.2 Recommendation

There are some possible future improvements to enhance this indoor farming monitoring system:

- Implement an "All in one" dashboard which display the data yet provide interactive control function.
- The light can be controlled by the microprocessor instead of manually controlled.
- Water level of container in irrigation system can be detected automatically.
- Implement chemical substances monitoring for soil.
- Apply analytical mechanism to analyse the growing stages of plants.

Reference

1. Tozzi, C. (2016). *IoT Past and Present: The History of IoT, and Where It's Headed Today*. [online] Talk in cloud. Available at: http://talkincloud.com/cloud-computing/iot-past-and-present-history-iot-and-where-its-headed-today [Accessed 6 Apr. 2017].
2. Research Gate. (2012). *Agricultural innovations for sustainable crop production intensification.* [online] Available at: https://www.researchgate.net/publication/258216861_Agricultural_innovations_for_sustainable_crop_production_intensification. [Accessed 6 Apr. 2017].
3. National Climate Assessment. (2014). *Agricultural.* [online] Available at: http://nca2014.globalchange.gov/report/sectors/agriculture [Accessed 6 Apr. 2017].
4. Lin, H., et (2015). *The Construction of a Precise Agricultural Information System Based on Internet of Things*. [online] iJOE. Available at: http://dx.doi.org/10.3991/ijoe.v11i6.4847 [Accessed 6 Apr. 2017].
5. Zhou, Y. and Duan, J. (2016). *Design and Simulation of a Wireless Sensor Network Greenhouse-Monitoring System Based on 3G Network Communication*. [online] iJOE. Available at: http://online-journals.org/index.php/i-joe/article/view/5736 [Accessed 6 Apr. 2017].
6. G. V., S. and SD, M. (2013). *Wireless Sensor Based Remote Monitoring System for Agriculture Using ZigBee and GPS*. [online] Atlantis-press. Available at: http://www.atlantis-press.com/php/download_paper.php?id=6287. [Accessed 6 Apr. 2017].
7. tutorialspoint. (n.d.). *SDLC Agile Model*. [online] Available at: https://www.tutorialspoint.com/sdlc/sdlc_agile_model.htm [Accessed 6 Apr. 2017].

8. Byteparadigm.com. (2017). *Introduction to I²C and SPI protocols – Byte Paradigm – Speed up embedded system verification*. [online] Available at: http://www.byteparadigm.com/applications/introduction-to-i2c-and-spi-protocols/ [Accessed 15 Aug. 2017].

9. Chakraborty, S. and Newton, A. (2011). Climate change, plant diseases and food security: an overview. *Plant Pathology*, [online] 60(1), pp.2-14. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-3059.2010.02411.x/full [Accessed 28 Jul. 2017].

10. Chaudhary, D., Nayse, S. and Waghmare, L. (2011). Application of Wireless Sensor Networks for Greenhouse Parameter Control in Precision Agriculture. *International Journal of Wireless & Mobile Networks*, [online] 3(1), pp.140-149. Available at: https://pdfs.semanticscholar.org/5f71/20d409a0eb7228f282c7898b50166762438e.pdf [Accessed 16 Jul. 2017].

11. Flores, K., Butaslac, I., Gonzales, J., Dumlao, S. and Reyes, R. (2017). Precision Agriculture Monitoring System using Wireless Sensor Network and Raspberry Pi Local Server. [online] Available at: http://ieeexplore.ieee.org/abstract/document/7848600/ [Accessed 18 Jul. 2017].

12. Limwiwattana, D., Tongkhao, K. and Na Jom, K. (2015). Effect of Sprouting Temperature and Air Relative Humidity on Metabolic Profiles of Sprouting Black Gram (Vigna mungoL.). *Journal of Food Processing and Preservation*, [online] 40(2), pp.306-315. Available at: https://www.researchgate.net/publication/283976006_Effect_of_Sprouting_Temperature_and_Air_Relative_Humidity_on_Metabolic_Profiles_of_Sprouting_Black_Gram_Vigna_Mungo_L [Accessed 14 Jul. 2017].

13. MSV, J. (2015). *Tutorial: Prototyping a Sensor Node and IoT Gateway with Arduino and Raspberry Pi - Part 1 - The New Stack*. [online] The New Stack. Available at: https://thenewstack.io/tutorial-prototyping-a-sensor-node-and-iot-gateway-with-arduino-and-raspberry-pi-part-1/ [Accessed 11 Aug. 2017].

14. Rhydolabz.com. (2015). *Raspberry Pi 2: Logging on to the 2nd generation*. [online] Available at: http://www.rhydolabz.com/wiki/?p=5782 [Accessed 11 Aug. 2017]

15. Quickcrop.co.uk. (n.d.). How to Grow Pak Choi (Chinese Cabbage) - Growing Guide. [online] Available at: https://www.quickcrop.co.uk/learning/plant/chinese-cabbage [Accessed 4 Mar. 2].
16. Webexhibits.org. (2008). Chlorophyll | Causes of Color. [online] Available at: http://www.webexhibits.org/causesofcolor/7A.html [Accessed 24 Mar. 2018].
17. www.tutorialspoint.com. (n.d.). SDLC Waterfall Model. [online] Available at: https://www.tutorialspoint.com/s

Appendices

Appendix A: Bi-weekly Report

FINAL YEAR PROJECT WEEKLY REPORT

(Project I)

Trimester, Year: Year 3 Sem 3	**Study week no.:** 3
Student Name & ID: CHONG KAI CHIAN 1503270	
Supervisor: DR GOH HOCK GUAN	
Project Title: INTERNET OF THINGS FOR INDOOR FARMING	

1. WORK DONE In week 3, a brief discussion about the project and components needed to be bought.
2. WORK TO BE DONE To implement the irrigation system and camera function in the project.
3. PROBLEMS ENCOUNTERED New components need to buy to implement the functions mentioned above.
4. SELF EVALUATION OF THE PROGRESS Waiting the component to be delivered before proceed to next step.

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Student's signature Supervisor's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project I)

Trimester, Year: Year 3 Sem 3	**Study week no.:** 9
Student Name & ID: CHONG KAI CHIAN 1503270	
Supervisor: DR GOH HOCK GUAN	
Project Title: INTERNET OF THINGS FOR INDOOR FARMING	

1. WORK DONE The new component has reached. This included the 9V motor, FC-28 soil moisture sensors, 4-channel relay module, 4mm water pipe and jumper wires.
2. WORK TO BE DONE Integrated the irrigation system and camera into the system.
3. PROBLEMS ENCOUNTERED Zero experience in using the relay module thus no much progress is done.
4. SELF EVALUATION OF THE PROGRESS Weak in time management. Have to follow the project timeline without delay.

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Student’s signature Supervisor’s signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project I)

Trimester, Year: Year 3 Sem 3	**Study week no.:** 10
Student Name & ID: CHONG KAI CHIAN 1503270	
Supervisor: DR GOH HOCK GUAN	
Project Title: INTERNET OF THINGS FOR INDOOR FARMING	

1. WORK DONE
Discuss with supervisor on how to use the relay module
2. WORK TO BE DONE
Integrated the irrigation system and camera into the system.
3. PROBLEMS ENCOUNTERED
N/A
4. SELF EVALUATION OF THE PROGRESS
Weak in time management. Have to follow the project timeline without delay.

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Student's signature Supervisor's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project I)

Trimester, Year: Year 3 Sem 3	**Study week no.:** 11
Student Name & ID: CHONG KAI CHIAN 1503270	
Supervisor: DR GOH HOCK GUAN	
Project Title: INTERNET OF THINGS FOR INDOOR FARMING	

1. WORK DONE The camera module is done implemented and a simple web page is designed to display the image captured by the camera.
2. WORK TO BE DONE Integrated the irrigation system into the system.
3. PROBLEMS ENCOUNTERED The soil was over compressed and making the pak choi has all died.
4. SELF EVALUATION OF THE PROGRESS No experience in growing plants with soil and need to regrow the pak choi again.

__________________________ __________________________

Student's signature Supervisor's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project I)

Trimester, Year: Year 3 Sem 3	**Study week no.:** 12
Student Name & ID: CHONG KAI CHIAN 1503270	
Supervisor: DR GOH HOCK GUAN	
Project Title: INTERNET OF THINGS FOR INDOOR FARMING	

1. WORK DONE The dashboard to display data has been updated. The irrigation system is done implemented.
2. WORK TO BE DONE Finish the FYP2 report. Burn the report into CD.
3. PROBLEMS ENCOUNTERED Accidently fell the farming container and make the new grown pak choi seedling died. The time to grow pak choi is not enough thus grow green beans and pakchoi together.
4. SELF EVALUATION OF THE PROGRESS Careless in handling the container. Need to regrow the pak choi.

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Student’s signature Supervisor’s signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project I)

Trimester, Year: Year 3 Sem 3	**Study week no.:** 13
Student Name & ID: CHONG KAI CHIAN 1503270	
Supervisor: DR GOH HOCK GUAN	
Project Title: INTERNET OF THINGS FOR INDOOR FARMING	

1. WORK DONE The FYP2 report is done
2. WORK TO BE DONE N/A
3. PROBLEMS ENCOUNTERED N/A
4. SELF EVALUATION OF THE PROGRESS Report has been completed.

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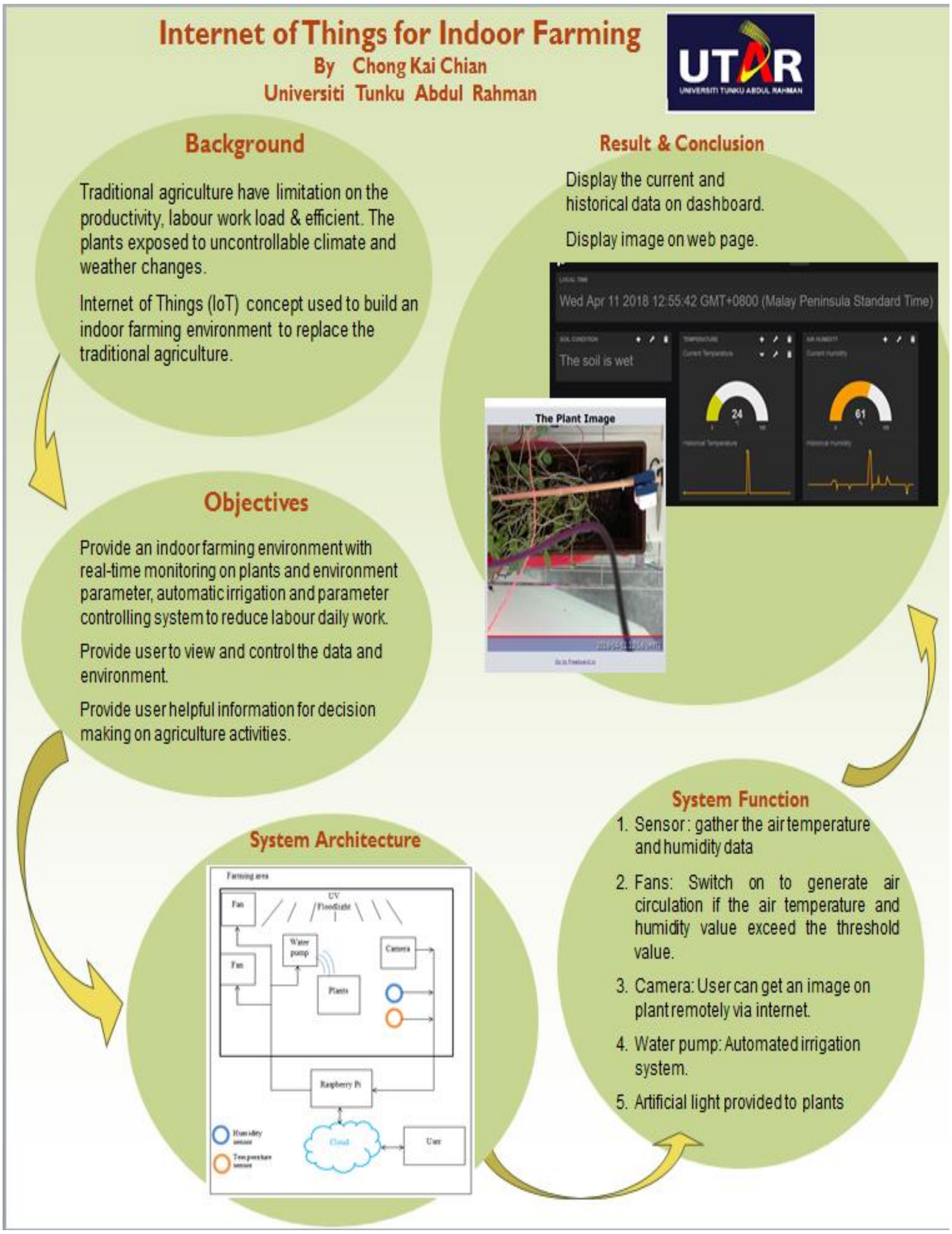
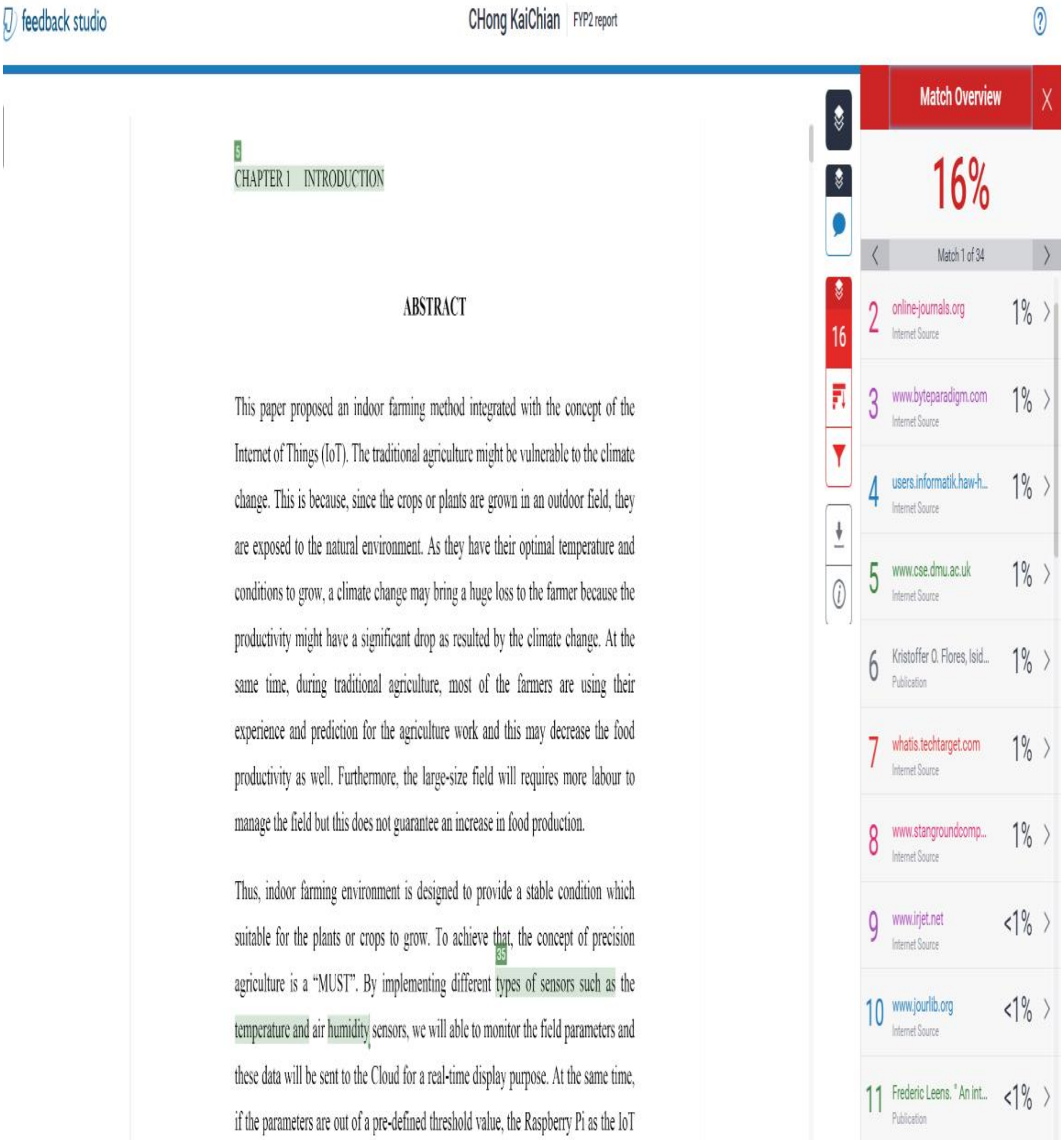
Student's signature Supervisor's signature

Appendix B: Poster



Appendix C: Plagiarism Check Summary



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