

**INTERNET OF THINGS ON WEB DEVELOPMENT
AND CLOUD COMPUTING FOR
SPACE FARMING**

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**INTERNET OF THINGS ON WEB DEVELOPMENT AND
CLOUD COMPUTING FOR SPACE FARMING**

by

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**Thesis submitted in fulfilment of the requirements for the
Bachelor's Degree of Engineering (Honours) (Aerospace Engineering)**

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ENDORSEMENT

I, Chai Rong Xing hereby declare that I have checked and revised the whole draft of dissertation as required by my supervisor



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DECLARATION

This thesis is the result of my own investigation, except where otherwise stated and has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any other degree.

A handwritten signature in black ink, appearing to read 'Chai Rong Xing', is written above a horizontal line.

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Without the support and advice of my parents and friends, no endeavour at any level can be done satisfactorily. Despite their hectic schedules, I would want to convey my heartfelt gratitude to my parents, who assisted me greatly in acquiring various information, collecting data, and mentoring me from time to time in making this project.

ABSTRACT

Food is a source of necessities we relied to survive and on planet Earth, we have the ability to grow all kinds of fruits and vegetables. Our goal of space exploration to far and beyond with the mission to preserve mankind someday is to send humans into space. The first crew of astronauts were to land on Mars in 2025. Food supply will not last them long enough to stay on Mars and return to Earth. Therefore, a space farming system that has the ability to produce fruits and vegetables in space has been researched throughout this project to solve the food supply problem. Mars has a completely different environment than Earth's. An enclosed farming system is designed from Solidworks software to fabricating the prototype where the plants are held within the system. Hydroponics technique is used where soil is being replaced by water. Microgravity is not the concern because our main focus is on the surface of Mars that has 62% lower gravity than Earth's. Environment in the enclosed farming system is monitored and regulated at all times using Internet of Things. The cherry tomato plant is experimented in this project where the optimal condition, pH level and TDS level required by the plant are determined. Sensors are placed in the enclosed farming system and a website is developed to monitor the cherry tomato plant. Acidic solution, alkaline solution, fertiliser solution and freshwater are prepared to regulate the condition of the cherry tomato plant autonomously. Firebase is used to transfer real-time data from the Raspberry Pi to the website hosted on Google Cloud. The real-time pH level, TDS level, temperature and humidity of the cherry tomato plant are recorded for four weeks, and the growth is analysed. During the fourth week, the cherry tomato plant died due to thermal shock. Nevertheless, monitoring and regulating the enclosed farming system are a success.

ABSTRAK

Makanan adalah sumber keperluan yang kita andalkan untuk bertahan hidup dan di planet Bumi, kita mempunyai kemampuan untuk menanam pelbagai jenis buah-buahan dan sayur-sayuran. Penghantaran manusia ke angkasa lepas adalah tujaun utama penerokaan angkasa lepas ke lokasi yang amat jauh dengan misi untuk memelihara manusia pada suatu masa nanti. Angkasawan yang pertama untuk mendarat di Marikh dijangka pada tahun 2025. Bekalan makanan tidak akan bertahan lama untuk angkasawan hidup di Marikh dan kembali ke Bumi. Oleh itu, sistem pertanian yang mempunyai keupayaan untuk menghasilkan buah-buahan dan sayur-sayuran di angkasa telah diselidik sepanjang projek ini untuk menyelesaikan masalah bekalan makanan. Marikh mempunyai persekitaran yang berbeza dari Bumi. Sistem pertanian tertutup direka bentuk dari perisian Solidworks dan prototaip dibina, dimana sayur-sayuran ditanam di dalam sistem tersebut. Teknik hidroponik adalah penggunaan air yang menggantikan tanah. Ketiadaan graviti tidak menjadi perhatian kerana fokus utama adalah pada permukaan Marikh yang mempunyai graviti 62% lebih rendah daripada permukaan Bumi. Persekitaran dalam sistem pertanian tertutup dipantau dan diatur menggunakan Internet of Things. Tanaman tomato ceri dieksperimen dalam projek ini di mana keadaan optimum, pH dan TDS yang diperlukan oleh tanaman ditentukan. Sensor diletakkan di dalam sistem pertanian tertutup manakala laman web dibina untuk memantau tanaman tomato ceri. Larutan asid, larutan alkali, larutan baja dan air tawar disediakan untuk mengubah keadaan tanaman tomato ceri secara automatik. Firebase digunakan untuk memindahkan data masa sebenar dari Raspberry Pi ke laman web yang dihoskan di Google Cloud. Tahap pH, tahap TDS, suhu dan kelembapan tanaman tomato ceri dicatat selama empat minggu dan pertumbuhan dianalisis. Pada minggu keempat, tomato ceri telah layu disebabkan oleh kejutan terma. Walaubagaimanapun, projek ini telah berjaya.

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LIST OF ABBREVIATIONS

IoT	:	Internet of Things
ISS	:	International Space Station
pH	:	potential of Hydrogen
HTML	:	Hypertext Markup Language
MQTT	:	Messaging Queuing Telemetry Transport
NFT	:	Nutrient Film Technique
TDS	:	Total Dissolved Solids
SD	:	Secure Digital
GPIO	:	General-purpose Input/Output
ADC	:	Analog-to-Digital Converter
VDD	:	Voltage Drain Drain
GND	:	Ground
SCL	:	Serial Clock
SDA	:	Serial Data
I2C	:	Inter-Integrated Circuit
H+	:	Hydrogen Ion
PPM	:	Parts Per Million
LED	:	Light-emitting Diode
BCM	:	Broadcom SOC Channel
SOC	:	System On a Chip
CSI	:	Camera Serial Interface
CSS	:	Cascading Style Sheets
API	:	Application Programming Interface

CPU	:	Central Processing Unit
RAM	:	Random Access Memory
OS	:	Operating System
SSH	:	Secure Shell Protocol
VM	:	Virtual Machine
IP	:	Internet Protocol
FPS	:	Frames Per Second

CHAPTER 1

INTRODUCTION

1.1 Background

The space farming is required to supply food for astronauts to survive. Astronauts are scheduled for mission-critical mission activities; thus, time is of the essence. Food can be grown in space in the same way that any other plant can be grown on Earth. However, it takes time, and growth must be monitored regularly. To avoid damage that may wipe out the entire food supply, the plants must be monitored and regulated at all times. This project is a spin-off technology from space to advance food security technology on Earth.

In this project, the main focus is developing an integrated Internet of Things (IoT) where every sensor and device can communicate to one another. An automated enclosed system will manage the farming system entirely out of human sight. Data will be connected to the cloud and constantly update the space operators from time to time, and they can monitor the farming system remotely. This system will save a significant amount of effort and time.

Hydroponics system is applied as the farming method. It uses water to substitute soil. However, in space, the presence of microgravity causes water to float. This project will experiment on Earth where microgravity is absent. So, the water floating-issue will be neglected throughout this project. Basil and cherry tomato were chosen as the main crop for this space farming experiment because they are easy to maintain, fast-growing, and high in dietary fibres and vitamins.

1.2 Problem Statement

Delivering food supply to space is expensive and uneconomical with increasing carbon footprint. NASA has been sending more and more astronauts to space. The cost of survival for every astronaut comes at a great cost. Thus, resupplying food is not ideal for the long run. Astronauts shall begin growing their own food supply in space to solve most of the problems. 'Space Farming' is introduced in this project to challenge the mission of growing food in space. Farming on the surface of Mars is the ultimate goal. Astronauts are tasked with important duties. Hence, they have limited time to sufficiently monitor and regulate the condition of the crops along with difficulty in determining the growth of the plant in a different environment. These difficulties can be solved by the implementation of IoT in the enclosed farming system to be designed and developed for this project.

1.3 Objectives

- i. To investigate and determine the physical condition required for a cherry tomato plant to grow optimally and cost-effective in a space-like environment
- ii. To develop an enclosed farming system using IoT and cloud computing integrated into the space farming prototype with a web application for monitoring and regulation of the farming system elsewhere in the world
- iii. To analyse the growth of the cherry tomato plant in the enclosed farming system

1.4 Thesis Outline

Chapter One comprises of Introduction, Problem Statement and Objectives outlining the project.

Chapter Two contain Literature Review concerning the architecture of farming in space and survival of mankind in space mission by producing their own food.

Chapter Three constitute the project's Methodology from ground zero to developing a fully functional space farming system. It covers the explanation of prototype design, IoT application, web development and cloud integration, and monitoring and regulation.

Chapter Four justifies the Result and Discussion of the entire experiment. Results covered are the monitoring data of the plant's pH level, TDS level, temperature and humidity.

Chapter Five unfolds the Conclusions and Recommendations, which suggests a probable outcome that can be used for future study and development.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews literature related to the architecture of farming in space, internet of things, cloud computing, web development and hydroponics.

2.1 Survival beyond Earth

In the mere future, space crew will need essential necessities to survive a long distance travel from one planet to another. This is a big leap in our era where scientists are developing new technology to support astronauts in the mission to Mars. Human space exploration has been limited to low Earth orbit and short visits to the Moon. All of these missions usually take only a few days to a few weeks. To extend the human exploration to the beyond, duration of the journey will increase significantly which can take up to years.

With current technology, transiting to and from Mars will take months to years to complete, with the stays in the sphere of influence of Mars ranging from a month to five hundred days (Arney et al., 2017). Opportunities for a Mars mission can only take place approximately every 2.1 years. For instance, a crewed mission in 2037 would result in transit times of 174 days travelling to Mars and another 201 days to return to Earth. The crew will be living on Mars for 539 days before departing back to Earth. A total of 914 days for a single Mars mission (Drake, Hoffman, & Beaty, 2010).

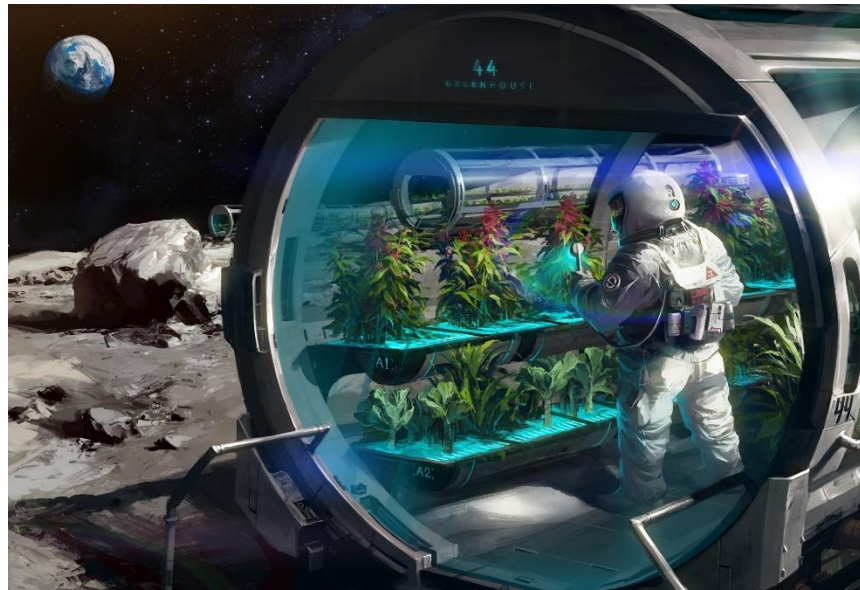


Figure 2.1 Illustration of Space Farming on Moon
 (“SPACE FARMING – SEDS KCT”, 2019)

In over two years, space crew will be dried up in food supply. This is because delivering cargo supply to a Mars mission is unreliable and high in cost. Thus, the space crew have to produce their own food supply to survive the mission. This is where space farming comes in. The space crew will be growing fresh foods with little effort in a compartment of the spacecraft.

2.2 Space Farming

The products that will be grown must be easy to handle, produce at an extensible amount of yield within a short period of time and the capability of reproducing with crop production scheduling. Life support for space crews on long-duration space missions to Mars will be heavily reliant on food supplies. Space farming is made possible for them to continue putting their effort into focusing the mission without worrying about food shortage (Y. Kitaya, Hirai, Wei, Islam, & Yamamoto, 2008).

For heat and gas exchanges between leaves and reproductive organs of plants and the atmosphere, the effects of sub-gravity or microgravity environments on inhibition of plant growth and reproduction are critical. Therefore, thorough regulation of air flow would be required to make environmental factors consistent inside the plant canopy and to improve heat and gas exchange between plants and the ambient air, hence promoting the growth of healthy plants in space farming under microgravity circumstances (Yoshiaki Kitaya, Hirai, & Shibuya, 2010).

In International Space Station (ISS), there is insufficient room for the growth fresh food due to oversize of hardware. As a result, astronauts continue to eat packaged food provided through cargo. However, experiments have been done on ISS which is pivotal for implementing plant growth system and will pave the way for the next long-duration space trip to the Moon (Carrillo, Morrone, Fusco, de Pascale, & Rouphael, 2020).

2.3 Internet of Things

IoT is a new trend of technology, and it is very popular today where it assists us in linking objects and mechanisms to the internet for remote control. For example, the hydroponics farming ecosystem uses IoT devices to monitor humidity, nutrient solution temperature, air temperature and pH. Mobile application is developed to make the system easier to control (Ruengittinun, Phongsamsuan, & Sureeratanakorn, 2017). The burden is reduced with the help of automation enabled by IoT, which uses various sensors to monitor the parameters of the plant environment.

As long as the development of other technologies continues its predicted path, IoT will overcome numerous challenges in security, processing capacity, and data mobility (Villamil, Hernández, & Tarazona, 2020). IoT allows agriculture, particularly arable farming, to become data-driven, to produce and operate farms more promptly and cost-effectively and, simultaneously, reduce their environmental impact (Villa-Henriksen, Edwards, Pesonen, Green, & Sørensen, 2020). IoT allows agriculture, particularly arable farming, to become data-driven, to produce and operate farms more promptly and cost-effectively and, simultaneously, reduce their environmental impact (Villa-Henriksen et al., 2020).

The agriculture industry requires a high degree of labour. Smart Farm watering system has been built using IoT for remote monitoring to enable informed decisions on watering the plants, making it the next technology of intelligent farming that does not require human labour (Hsu et al., 2021). Smart agriculture, also known as smart farming, uses the IoT to crop cultivation with the potential for labour and resource savings, finer-grained control over-irrigation and fertilising, and data collection with higher precision about the planting environment (Changmai, Gertphol, & Chulak, 2018).

2.4 Cloud Computing

Data processing and data storage infrastructure that operates outside of our mobile and desktop is cloud computing. The main goal of cloud computing and IoT are the interaction and cooperation between data sent via wireless network to fulfil an objective that makes both of the integration as a combined entity. Cloud computing technology enhances the function of IoT (Stergiou, Psannis, Kim, & Gupta, 2018).

With the development of broadband internet, cloud computing has enabled many of today's corporate demands to be handled more efficiently and effectively in a remote server rather than owning an expensive server that takes up space and requires maintenance (Martins, 2020). Numerous tasks, including web hosting and file storage, are part of the cloud solution.

Figure 2.2 shows one of many Google's datacenters around the world. Using these technologies, it is now possible to construct and build a modern cloud infrastructure for any project. As a result, Google Cloud and other popular cloud platforms such as Amazon Web Services and Microsoft Azure have revolutionised the era of software development and operations.



Figure 2.2 Google Datacenter

Firebase, part of Google's new technology development, can handle large amounts of unstructured data catered for web applications that have become more reliant upon huge amounts of database (Khawas & Shah, 2018). Real-time database server provided by Firebase service along with a host of different cloud features. Firebase makes it relatively simple for developers to create communication-based applications (Chatterjee, Chakraborty, Decosta, & Nath, 2018). Data captured by the IoT can be used to send real-time to the cloud via Firebase to be monitored and interpreted.

2.5 Web Development

Because of the competitive character of modern living, a dynamic and accessible web infrastructure has become crucial. Working online systems have made agile approaches particularly ideal for constructing such systems to increase productivity, permit continuous contact with users, and improve the flexibility and quality of the Web developed (Maleki & Ramsin, 2018). Before web development projects, the success of the attempt is determined by selecting the best-suited approach that corresponds to the description of what the users want to see.

HTML platform is well-suited for executing real-time IoT Web applications. However, the latency of sensor data message delivery and throughput rate are used to measure the web performance (Babovic, Protic, & Milutinovic, 2016). Therefore, the most appropriate messaging protocol for a broad set of IoT Web applications is Message Queuing Telemetry Transport (MQTT) a publish-subscribe network protocol is used to deliver messages between devices (Mishra & Kertesz, 2020).

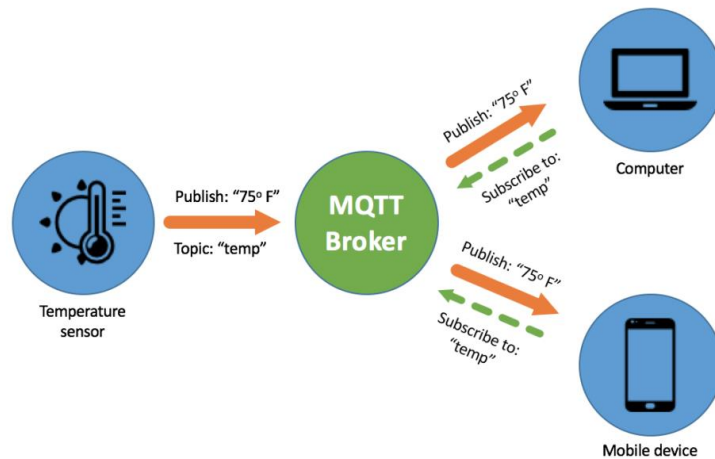


Figure 2.3 MQTT Control Packet (“API Builder and MQTT for IoT”, 2018)

2.6 Hydroponics Farming System

Hydroponics is a soilless farming method in which the farming systems cultivate plants in a medium-based aquatic environment. Hydroponic systems use mineral fertilisers to feed the plants in the soilless media (Alshrouf, 2017).

There are a variety of hydroponic farming techniques to be considered, one of them is the nutrient film technique (NFT). NFT works in such where a shallow stream of water carrying dissolved nutrients recirculates through the bare roots of plants in a channel with one end slightly higher than the other, forming a slope in which the water may easily flow past (Mohapatra, Chandan, Panda, Majhi, & Pillai, 2020). Then, a pump is used to deliver the nutrients to the channels and the unused nutrient solution is recycled over and over again.

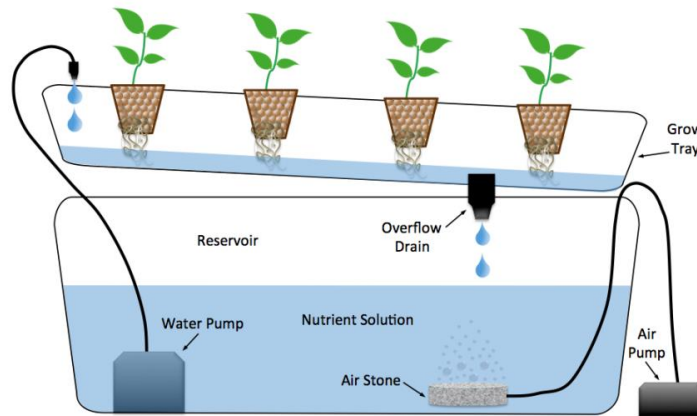


Figure 2.4 Nutrient Film Technique (“Hydroculture & Hydroponics”, 2016)

There are more hydroponics techniques such as ebb and flow, wicking, drip systems and aeroponic. Nevertheless, the best technique that will be used in the project is the deep water culture technique. The deep water culture is a hydroponic method of plant cultivation that involves suspending the plant roots in a nutrient-rich solution. This approach typically employs a rectangular tank filled with solution rich in nutrients, with the plants floating on top of Styrofoam boards (FAO, 2018).

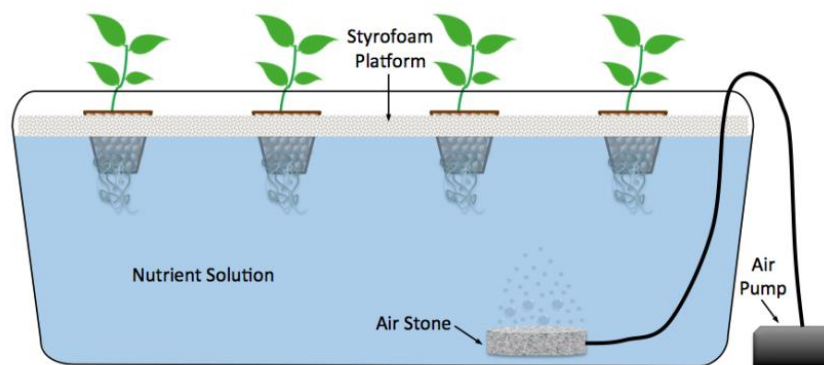


Figure 2.5 Deep Water Culture (“Hydroculture & Hydroponics”, 2016)

A few things had to be kept under control in the deep water culture. The pH level is an essential consideration. The pH level is essential in ensuring that the plant absorbs the greatest nutrient elements required. The maximum and minimum pH levels required by the plant has to be determined. A system must be developed to automate monitoring and control of pH levels based on hardware, programming, and functionality testing (Saaid, Yassin, & Tahir, 2020).

Another factor that will be considered is the total dissolved solids (TDS) level of the solution. TDS is a measurement of the dissolved combined content of all inorganic and organic compounds in a solution. The fertiliser used in the deep water culture hydroponics system is combined into the water, which is referred to as the nutrient solution (Eridani, Wardhani, & Widiyanto, 2017). TDS is measured as a volume of water with parts per million (ppm). Nonetheless, TDS play an important role in providing nutrients to plants. It is significant to discover the amount of TDS needed to be absorbed by the plant.

Fertiliser A and fertiliser B will be used in the hydroponics system. Fertilizer A contains potassium, whereas fertiliser B contains sulphate and phosphate. The AB mix nutrition is relatively expensive but help to facilitate growth of tomato cherry plant (Dewi, Rahayu, & Bashri, 2019).

CHAPTER 3

METHODOLOGY

Within this chapter the prototype configuration is defined with design of the prototype, different type of sensors and devices used, the optimum requirement required by cherry tomato plant, building of monitoring and regulation task using IoT application, web development and cloud integration.

3.1 Farming System Design

An enclosed farming system is built to simulate the earth environment. The farming system can be placed in different parts of the world with the harsh condition, yet it can continue to sustain the optimal required condition for the plant to grow. For instance, the enclosed farming system can be brought to planet Mars which has a completely different environment than Earth's. However, with IoT implemented into the enclosed farming system, different kinds of plants grown on Earth can be grown within the system on Mars. It has its own internal environment that is continuously tuned to maintain an ideal condition for the plant's growth.

3.1.1 Solidworks Design

The enclosed farming system was initially sketched out in Solidworks to acquire a basic idea of the prototype that would be produced with accurate measurements for the best visualisation. The enclosed farming system has a similar concept to a transparent tank called a terrarium. Figure 3.1 shows the 3D model computer-aided-design of the enclosed farming system at an isometric projection.

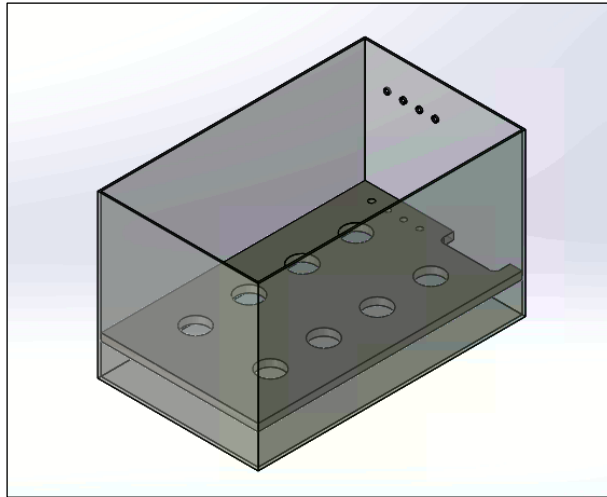


Figure 3.1 CAD Drawing of Enclosed Farming System

Then, the dimension of the enclosed farming system is sketched to provide a more convenient layout during the construction of the prototype. The dimensions are mostly to give a better view of the positions of the holes to be drilled.

Based on Figure 3.2, the four holes on the top right are for the insertion of silicone tubes. The other four holes on the left are for connecting wires linking the sensors inside the enclosed farming system to the Raspberry Pi 4 outside.

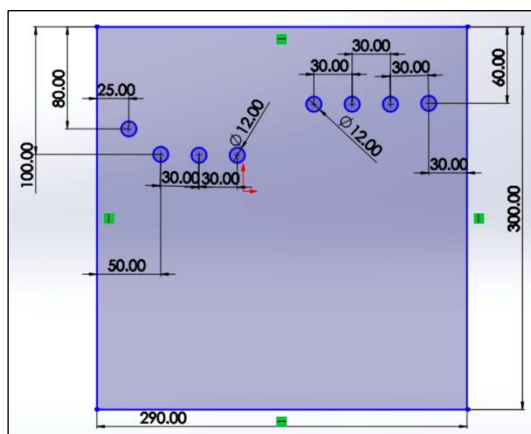


Figure 3.2 Dimension Sketch of Enclosed Farming System (Side)

In Figure 3.3, the plant holder is designed where eight of the big holes are for the net cups of the plant to be held. Four of the small holes on the left are for the insertion of silicone tubes. The 30 mm x 90 mm rectangle hole is reserved for the placement of sensors.

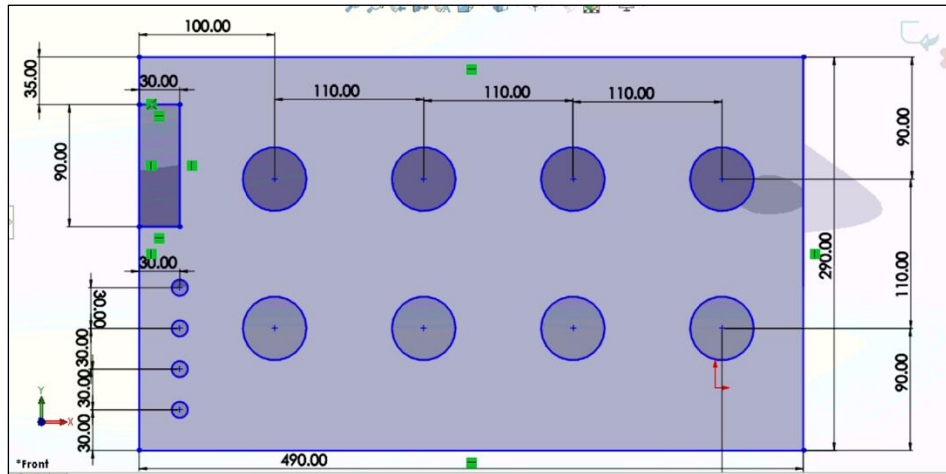


Figure 3.3 Dimension Sketch of Enclosed Farming System (Plant Holder)

3.1.2 Building of Enclosed Farming System

Acrylic (Perspex) is used to build the tank shape of the enclosed farming system. Every piece of acrylic has a thickness of 5 mm. The acrylics are sealed together using silicone sealant on every side except for the top. As described in Figure 3.2, the holes are drilled on one side of the acrylic. The four holes on the top right are for the insertion of four silicone tubes and the rest of the holes are for the fitting of sensor wires.

Meanwhile, the plant holder in Figure 3.3 is made out of polystyrene with a thickness of 20 mm. Eight large holes are cut evenly, where the net cups will rest between the holes. The four small holes are for the continuation of the silicone tube insertion. The rectangular-cut will be the stationing of the sensors. Because the farming system is built using the application of deep water culture, a hydroponic method of plant production by means of plant roots are suspended in the solution, and the polystyrene will be resting about two thirds from the top of the tank.



Figure 3.4 Prototype of Enclosed Farming System

3.2 IoT Application

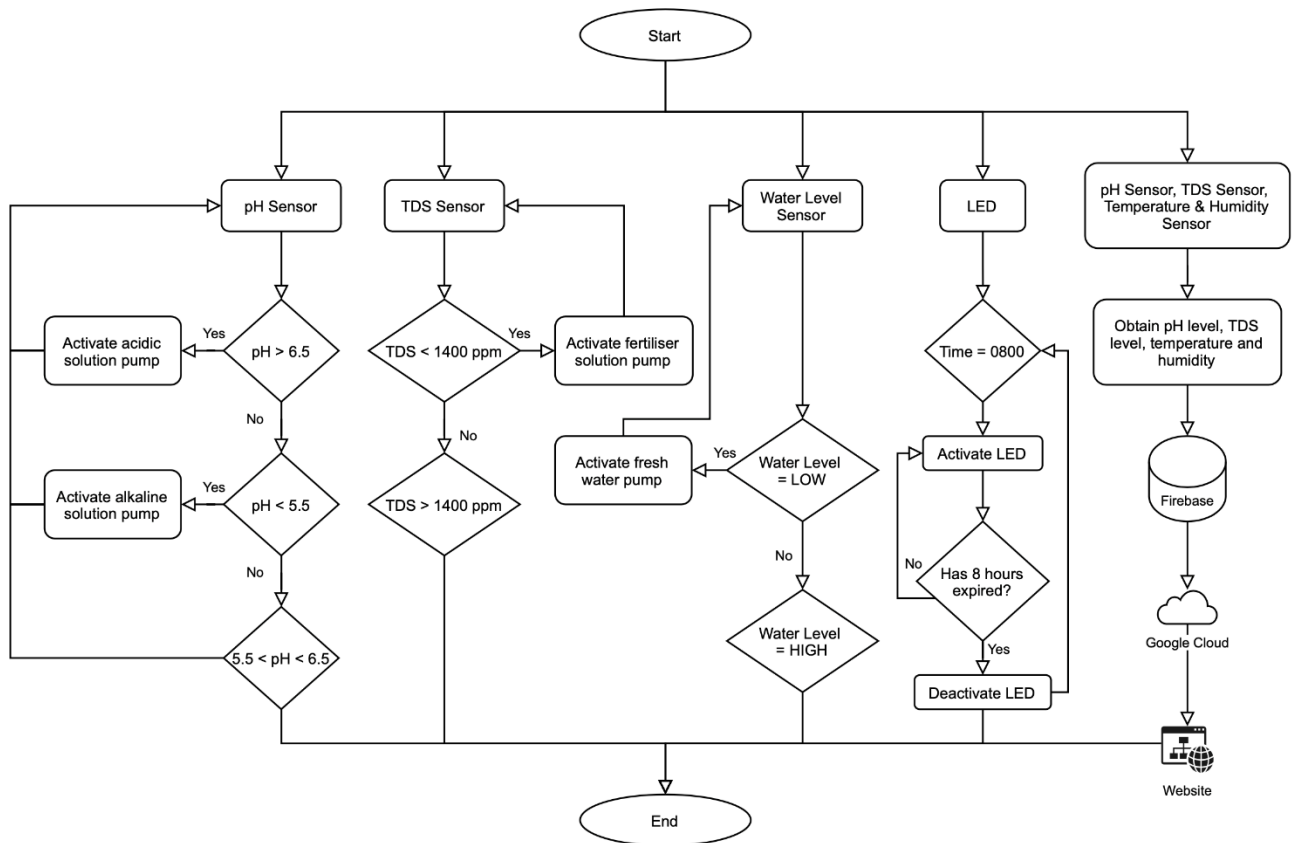


Figure 3.5 Complete Flowchart of Monitoring and Regulation of Enclosed Farming System

The IoT will assist the growth of the plant in the enclosed farming system. Multiple sensors are attached within the enclosed farming system to read different parameters of the internal environment's condition and produce various outputs accordingly to maintain and regulate the internal environment suited for the plant's growth. The IoT system will be designated to automate the internal environment without human assistance and presence. However, shall there be any reach of human intervention or regular observation, recorded data of the internal environment will be logged consistently and stored on the internet for all sorts of monitoring. Figure 3.5 shows the complete flowchart of the monitoring and regulation of enclosed farming system.

3.2.1 Designing IoT Architecture

Raspberry Pi 4 Model B (4GB RAM) will be used as the computer that operates most of the heavy task throughout the IoT application. Four different sensors are placed in the enclosed farming system's internal environment to automate the farming system:

- i. **DHT11 Humidity and Temperature Sensor** to measure the temperature and humidity of the internal environment (air)
- ii. **Analogue pH Sensor** to measure the pH level of the solution
- iii. **Analogue TDS Sensor** to measure the total dissolved solids level of the solution
- iv. **Water Level Sensor** to measure the water level of the solution

In Figure 3.6, four of the sensors are stationed in the internal environment of enclosed farming system.

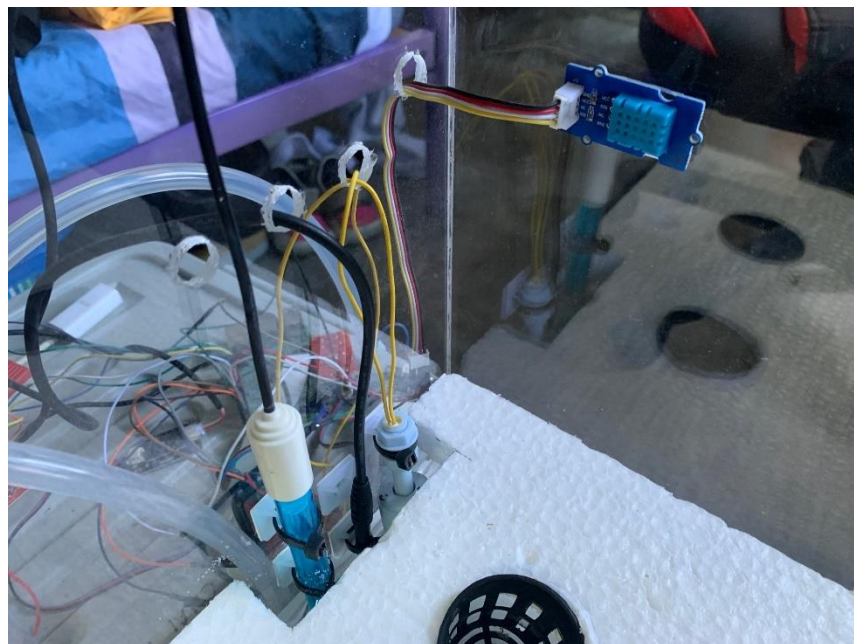


Figure 3.6 Internal Environment Sensor Station

In Figure 3.7, four of the silicone tubes are inserted from the variable solutions in the external environment then, into the internal environment of the enclosed farming system via the four holes that are drilled on the side of the acrylic and ending on the four holes of the plant holder.

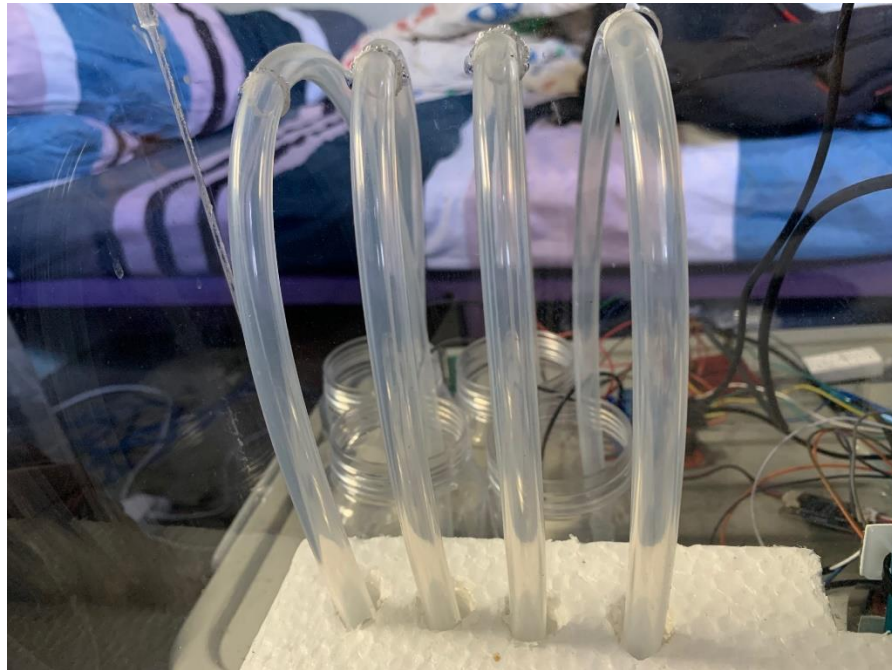


Figure 3.7 Insertion of Silicone Tubes between Internal Environment and External Environment

As real-time data obtained from the sensors, data from the reservoir will be regulated by four **Micro Submersible Water Pump**. Each pump positioned outside of the enclosed farming system will fill different solutions into the internal environment via the silicone tubes depending on the optimum condition for the plant. Variable solutions to be used for the reservoir regulation are **acidic solution**, **alkaline solution**, **fertiliser solution**, and **freshwater**, as shown in Figure 3.8.



Figure 3.8 Variable Solutions

Based on Figure 3.8, the orange coloured solution is the highly acidic solution containing citrus flavour. The light blue coloured solution is the alkaline solution that has a small amount of ordinary baking soda. Both of these solutions will control the pH levels of the reservoir inside the internal environment. The transparent solution at the back on the left is freshwater and on the right is the fertiliser solution consisting of a mixture of fertiliser A and fertiliser B, as shown in Figure 3.9.



Figure 3.9 Fertiliser A and Fertiliser B

As shown in Figure 3.10, there are two different environments separated for this system. Within the enclosed farming system holds the internal environment where the pH probe, TDS probe, humidity and temperature sensor, and water level sensor will be stationed on the rectangular cut of the polystyrene plant holder. Raspberry Pi 8MP Camera on the other hand, is placed at the corner inside of the enclosed farming system. Meanwhile, the external environment as shown in Figure 3.11 is the dry workstation where non-waterproof equipment is stationed outside the enclosed farming system. That includes Raspberry Pi, pH signal conversion board, analogue TDS meter and four-channel relay module. However, the micro submersible water pumps are placed in a different container containing different variable solutions outside.

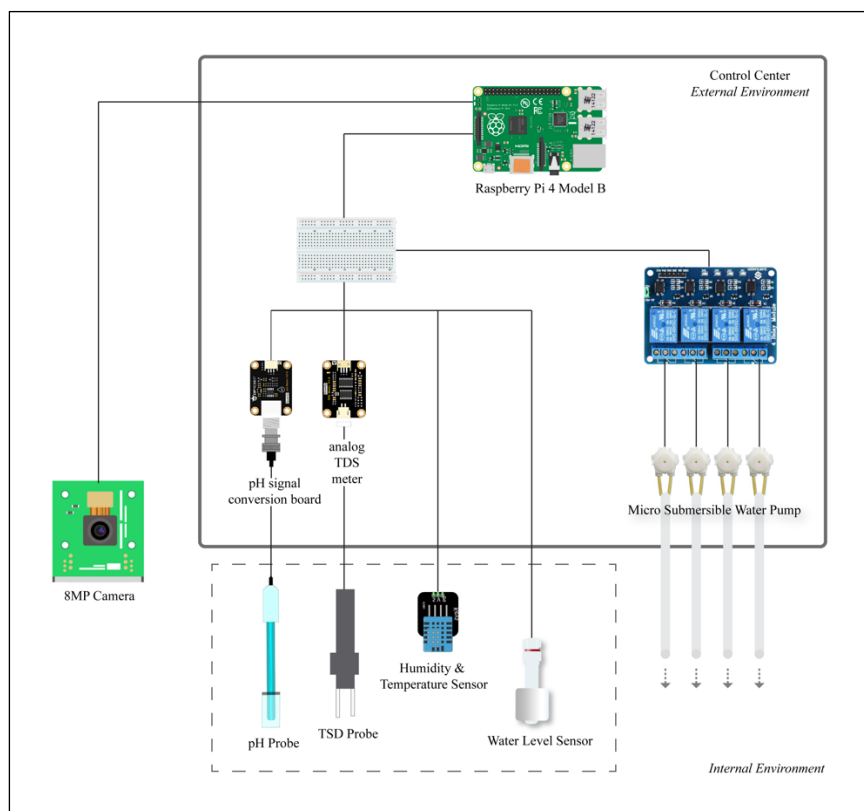


Figure 3.10 Diagram of IoT Integration Design

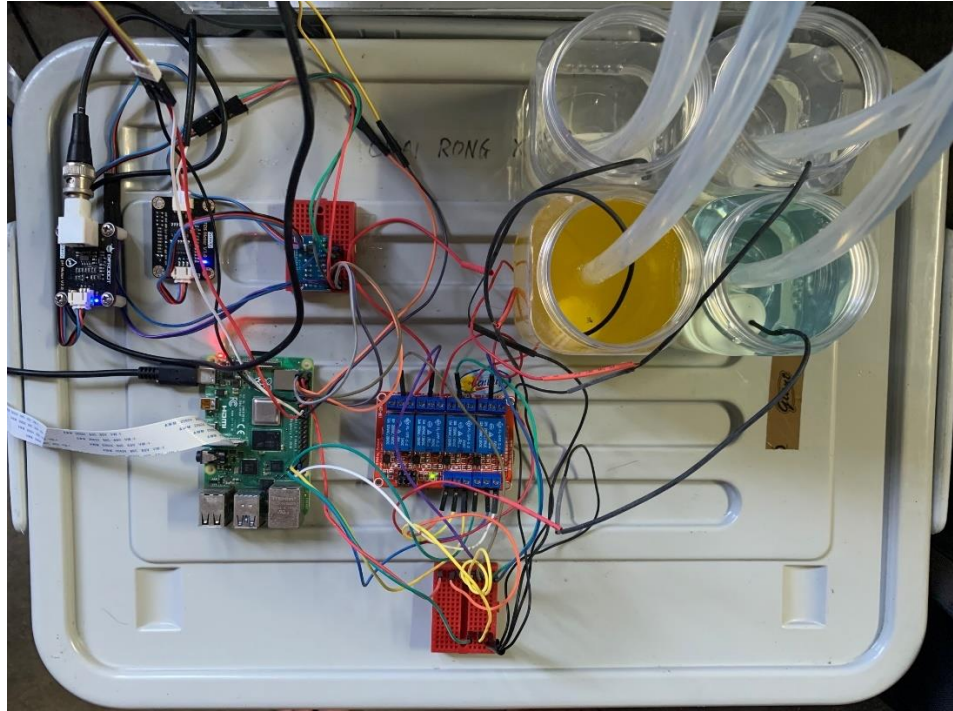


Figure 3.11 External Environment Workstation

3.2.2 Raspberry Pi 4 Configuration

The Raspberry Pi 4 shown in Figure 3.12 functioned as the brain of the entire system. It is powerful enough to power the sensors, upload real-time data to the internet and perform automated task non-stop, every second, everyday.



Figure 3.12 Raspberry Pi 4 Model B

The Raspberry Pi is connected to a monitor, keyboard, mouse and ethernet cable. An 8GB micro SD card containing Raspbian Pi OS is inserted into the Raspberry Pi. All necessary installation and setup are configured, and a new Raspberry Pi Desktop is readily to be used. Most of the commands had to be manually run on the Linux terminal command prompt.

GPIO (general-purpose input/output) pins are a powerful feature of the Raspberry Pi. These pins are physical interface where connections are to be made between the Raspberry Pi and different sensors. 3.3V and 5V are the power supply pin and GND is for ground connection. Throughout the project, Figure 3.13 is used as a reference on determining which sensors are hooked to which pin on the Raspberry Pi.

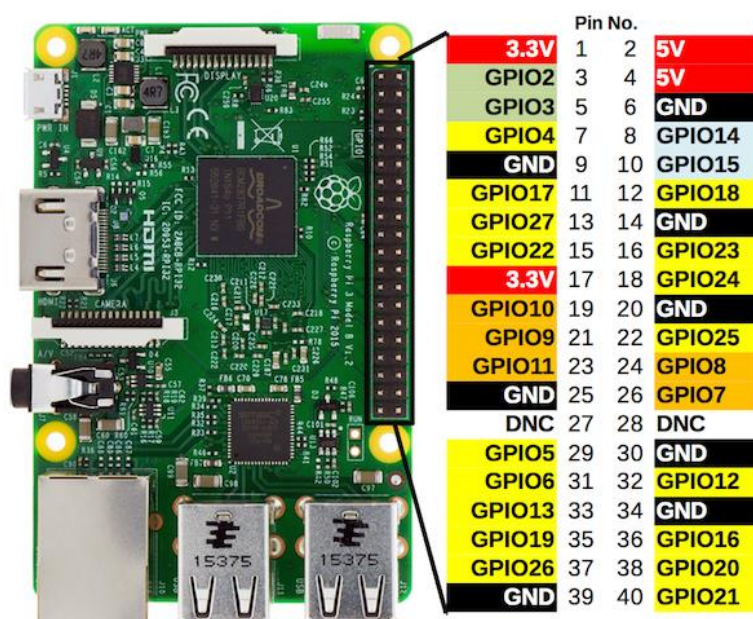




Figure 3.13 Raspberry Pi 4 GPIO Pin No

3.2.3 Functions of Sensors and Devices

There are four sensors in this project that will be collecting real-time parameters, which are the pH level, TDS level, water level, and temperature and humidity of the environment (refer to Figure 3. 14 to 3. 20). Meanwhile, there are four devices, the micro submersible water pump that are responsible for controlling the condition of the reservoir by changing the pH level, TDS level and water level. Additionally, a Raspberry Pi camera is used to livestream a video of the growing plant for monitoring purposes.

Table 3.1 Functions of Sensors and Pin Location

Sensors	Pin
 <p>Figure 3.14 Gravity: Analogue pH Sensor</p>	<p>To measure pH level of the solution</p> <p>A1*</p>
 <p>Figure 3.15 Gravity: Analogue Water TDS Sensor</p>	<p>To measure the total dissolved solids level of the solution</p> <p>A0*</p>