STUDY ON DESIGN AND CONTROL OF AN INDOOR AUTOMATIC HYDROPONIC FARMING MACHINE 2018

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FACULTY OF MECHANICAL ENGINEERING

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FINAL YEAR PROJECT REPORT

STUDY ON DESIGN AND CONTROL OF AN INDOOR AUTOMATIC HYDROPONIC FARMING MACHINE

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HO CHI MINH CITY, 2018

ABSTRACT

Hydroponics is a widely and frequently used technique for growing plants without soil, providing for a considerable degree of control of the elemental environment surrounding the root. This study focuses on designing and controlling an indoor automatic hydroponic machine that is suitable for urban area to solve the need of stable vegatable supply and house decoration. The machine is also designed to be easily extended to become an aquaponics system (combination of aquaculture and hydroponics). The machine has capability to connect to Internet. Therefore, all sensors' data can be stored on an online database and the machine can be monitored and controlled remotely though a mobile application.

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CHAPTER 1: INTRODUCTION

1.1. Motivation

Ever since, fresh vegetables have always been recognized as a source of human nutrition, fiber and vitamins necessary for the body's functioning [1][2]. However, People in Vietnam are facing trust issue in hygiene and safety of food. Irreponsible farmers are using stimulants and pesticides that exceed the allowed level. Besides, urban people want to have green space and aquarium in their house for decoration, so that it becomes more comfortable and environmentally friendly. Therefore, people living in the urban zone are finding a way to grow their own food at home. However, because of hustling pace and limited space of urban life, they are having trouble doing so.

Therefore, optimizing the area of the garden (vertical farming) along with the automation of the process of quality control and caring of vegetables is the key to ensure the needs of the people.

1.2. Past research efforts

Before this study, some projects in the field of precision farming using soil and soilless technique were made and gained certain experiences.

1.2.1. Farmbot Genesis prototype

The objective of this project was to replicate Farmbot Genesis, an open-source project [3]. Farmbot Genesis is a vegetable cultivation machine with CNC-controlled three cartesian axis system that can perform sowing, watering and humidity measurement by farming method. Suitable size is located in the balcony, yard of small households living in urban areas.

Figure 1.1 Farmbot Genesis prototype are woking

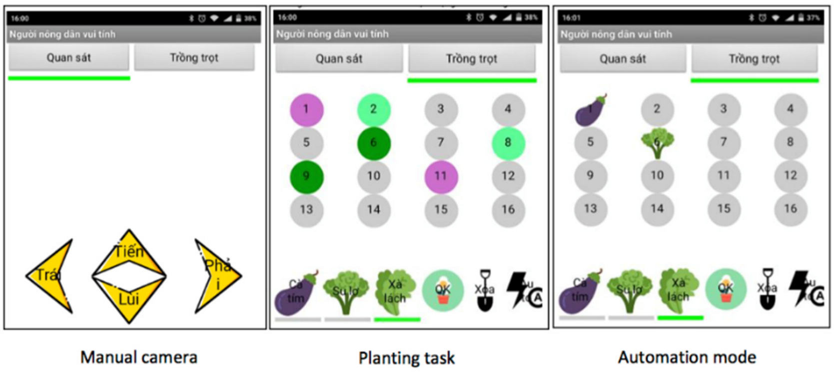

Figure 1.2 Android application to monitor and control the machine

1.2.2. Rotating farming machine

This project using rotating mechanism of Ferris wheel as the way of vertical farming to saving space. The water supply and artificial light are integrated on the bar above. The pots are numbered orderly, they are controlled to reach to the top position so they can be watered and received artificial light for photosynthesis process.

Figure 1.3 3D model and prototype of rotating farming machine

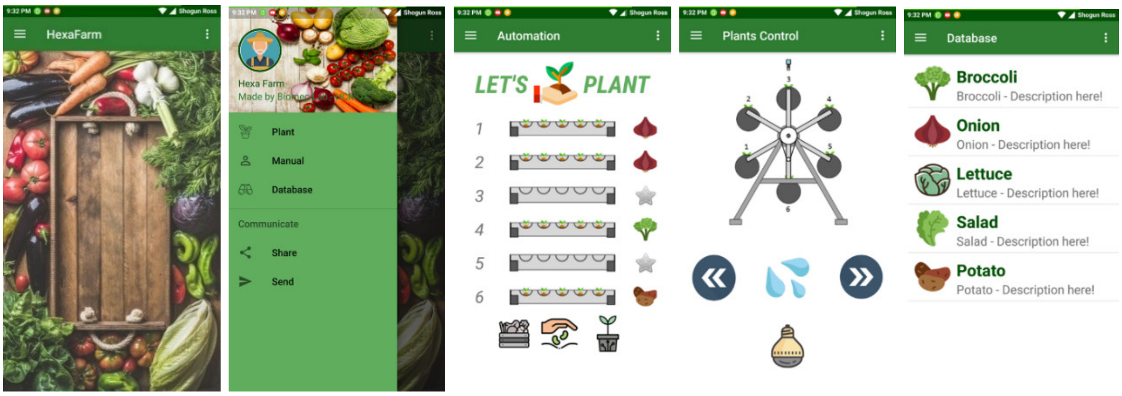

Figure 1.4 Android application to monitor and control the machine

1.2.3. Nutrient Film Technique (NFT) hydroponic system

Two previous projects above used conventional farming technique (using soil), so they have some disadvantages such as easily encountering diseases which are left in soil form the previous crop, soil will be crushed and hardened after a period of cultivation, etc.

Therefore, this study focuses on using hydroponics technique and a project were made to gain experience of the technique. A nutrient film technique hydroponic system was assemblied at my home. The system worked very well and gave a great productivity. However, the system was not fully automated. It is only timed to pump solution, but the process of dosing and checking nutrients into solution must be done manually.

Figure 1.5 Nutrient Film Technique (NFT) hydroponic system

1.3. State of the art

1.3.1. Hydroponic rotating cage

Hydroponic rotating cage is a form of static hydroponic technology. The principle of this technique is to alternately immerse the roots in the solution to absorb the nutrients by a rotating mechanism.

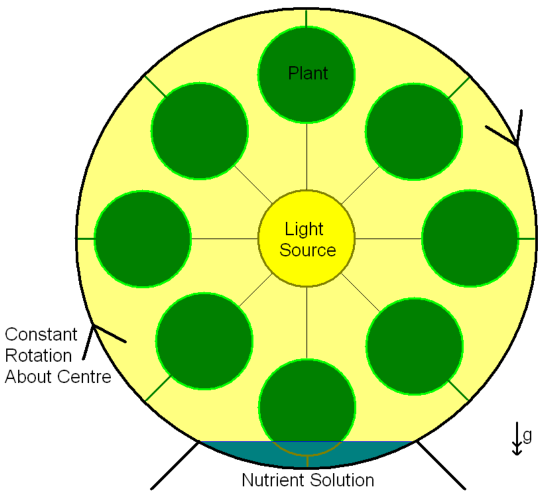

Figure 1.6 Working principles of hydroponic rotating cage [4]

Nutrient solution is stored in a tank with premixed nutrient concentrations suitable for plant growth. Plant specimens are mounted on each side of the horizontal bar with exposed roots. When each bar reaches the bottom, the roots of the individual trees on the bar are exposed to nutrient water and absorbed. In this system, the artificial light source in this type of structure will be at the center. The plants grow in this central spotlight for growth light.

- Advantages
    - Saving space.
    - No need for sunlight, make full use of artificial light source.
- Disadvantages
    - Consume high power.
    - The structure is relatively complicated, difficulty in fabrication leading to high cost.

In addition, this system has a prominent advantage but also a disadvantage. The cage structure of the system helps the plant to grow from top to bottom, gravitation stimulates plant growth. However, this feature applies only to small trees (vegetables, herbs, etc.). Plants with relatively large weights (mulberry, tomato, etc.) shall not be planted in this system because the tree will be tilted and the tree may be broken [4].

Volksgarden's Omega Garden Hydroponics Design, Canada is a featured example of this model that has been commercialized in the market [4].

Figure 1.7 Single and double Volksgarden's Omega Garden Hydroponics system. [4]

In addition, the rotating hydroponic system is also highly distinctive and aesthetically designed by DesignLibero with a product called the Green Wheel [5].

Figure 1.8 Appearance and parts of the Green Wheel. [5]

1.3.2. Indoor aquaponics system

Conventional aquaponics systems are generally bulky in size and separate components. Therefore, an area of greater than 4 m^2 is needed for installation. For small apartments or houses, installing this system is very difficult. In addition, the aesthetics of conventional aquaponics systems are not good. Since then, a trend toward the design of aquaponics systems, aesthetically and appropriately placed indoor such as living room, kitchen was formed and quite favored. Since 2014, a number of indoor aquaponics systems have been developed by research teams and have so far begun to commercialize their products. Some of the outstanding products are: Grove Ecosystem by MIT engineering team, Lybox Ecosystem by Lybox, EcoQube, etc [6] [7] [8].

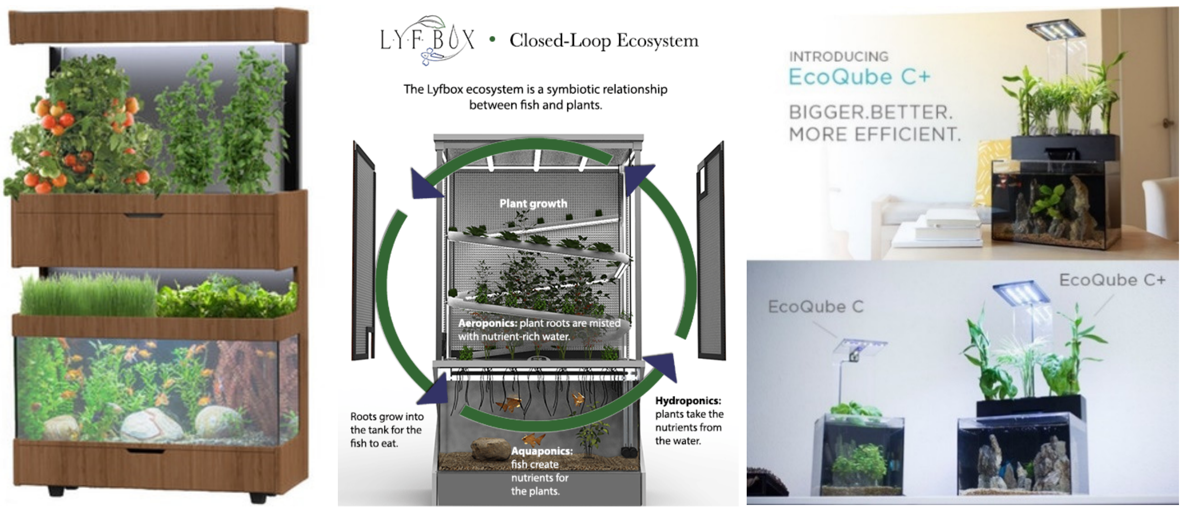

Figure 1.9 Commercialized aquaponics system. [6] [7] [8]

1.4. Objective and scope

1.4.1. Objective

- Research on design and control indoor farming machine at the house using hydroponic technique. Machine should be designed to be easily extented to become an aquaponics system.
- The machine targets the urban small-area house or the apartement. Therefore, the machine should be small in size, can be set next to window or balcony.
- Applied the IoT technology to control and monitoring the machine through the smart phone (using ip camera system to observe, automate the process of dosing nutrients and collect and store data online about indexes such as EC, pH, solution’s temperature, environmet’s temperature, moisture and light intensity).

1.4.2. Scope

- Learn about the methods of growing hydroponic plants.
- Learn about the cultivation and care of plants using hydroponic methods.
- Study on design of mechanical module of the machine.
- Study on design of control module of the machine.
- Study on application of IoT technology in control and monitoring the machine.
- Experimental verification (if conditions permit).

CHAPTER 2: STUDY ON HYDROPONIC TECHNIQUE

2.1. Introduction

Hydroponics is a subset of hydroculture, which is the growing of plants in a soil less medium (coir, gravel leca, cotton, etc.) or an aquatic based environment. Hydroponic growing uses mineral nutrient solutions to feed the plants in water, without soil [9].

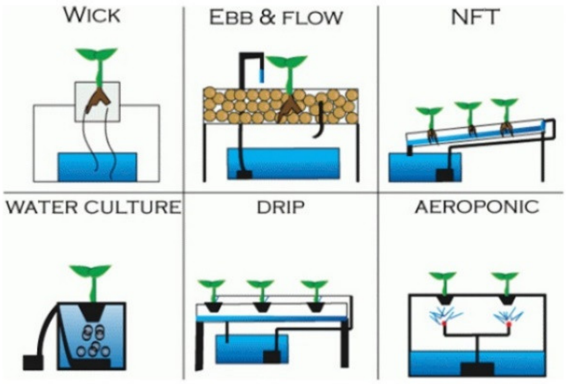

Figure 2.1 Type of hydroponic system. [10]

Advantages of hydroponics:

- Easy to provide nutrients for each stage of vegetable development.
- Can be easily deployed as vertical farming system. Therefore, save space, take advantage of the extra space in the house such as balcony, terrace, etc.
- Save time for caring. The manual work in the process of caring and raising large trees are reduced compared to traditional farming methods.
- Due to not use soil, no pathogens presented in the soil exist.

Disadvantages of Hydroponics:

- In order to invest in a modern, high-quality hydroponic system, growers often have to spend a considerable amount of money.
- Growers require a certain level of understanding of the vegetables.
- The source of nutrients for vegetables is chemical products, so choosing the right products will not seriously affect the quality of vegetables.

2.2. Important parameters in hydroponic

In hydroponics, all the essential nutrients supplied to plants are used as inorganic mineral salts that are soluble in water solvents. The success or failure of hydroponics is dependent on the nutrient solution through the pH value and the total soluble solids TDS in the hydroponic solution.

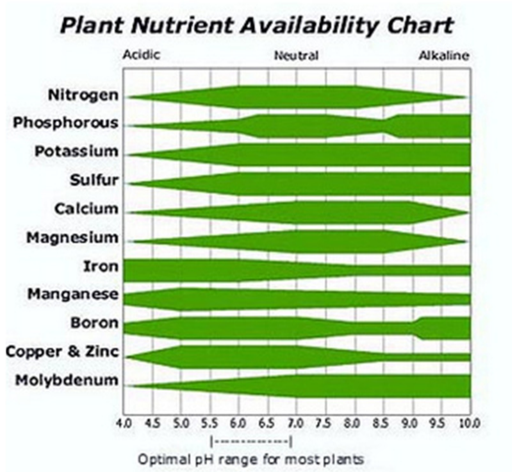

Figure 2.2 Plant nutrient availability chart. [11]

Table 2.1 Necessary nutrients and their concentration in solution. [12]

Substance	**Ion**	**TDS (ppm)**
Nitrogen	Nitrate (NO_3^-), Ammonium (NH_4^+)	100 ~ 250
Phosphorus	$H_2PO_4^-$, PO_4^{3-}, HPO_4^{2-}	30 ~ 50
Potassium	Potassium (K^+)	100 ~ 300
Calcium	Calcium (Ca^{2+})	80 ~ 140
Magnesium	Magnesium (Mg^{2+})	30 ~ 70
Sulfur	Sulfate(SO_4^{2-})	50 ~ 120
Iron	Fe2+, Fe3+	1.0 ~ 3.0
Copper	Copper (Cu^{2+})	0.08 ~ 0.2
Manganese	Manganese (Mn^{2+})	0.5 ~ 1.0
Zinc	Zinc (Zn^{2+})	0.3 ~ 0.6
Molybdenum	Molybdate (MoO_4^{2-})	0.04 ~ 0.08
Boron	BO_3^{2-}, $B_4O_7^{2-}$	0.2 ~ 0.5
Chloride	Chloride (Cl^-)	< 70
Sodium	Sodium (Na^+)	< 50

So, pH meter and EC meter (EC meter is commonly used to measure TDS) are used. Besides, liquid temperature sensor is needed for temperature compensation of EC parameters and supervision of the temperature of the solution.

CHAPTER 3: DESIGN OF MECHANICAL MODULE

3.1. Working principle

1.Motor; 2.Transmission; 3.Bearing; 4.Rotating disc; 5.Photosynthesis LED bar; 6.Pot; 7.Pot-support bar; 8.Rotating bar; 9.Support frame; 10.Water line; 11. Solution container (C1, C2); 12.Submersible pump; 13.Peristaltic pump (B1, B2, B3); 14.Nutrient A; 15.Nutrient B; 16.pH down solution; 17.Solenoid valve (V1, V2, V3, V4); 18.Float switch; 19.Air pump; 20.Air bubbling rock; 21.pH meter; 22.TDS meter; 23.Liquid temperature sensor; 24.Check valve.

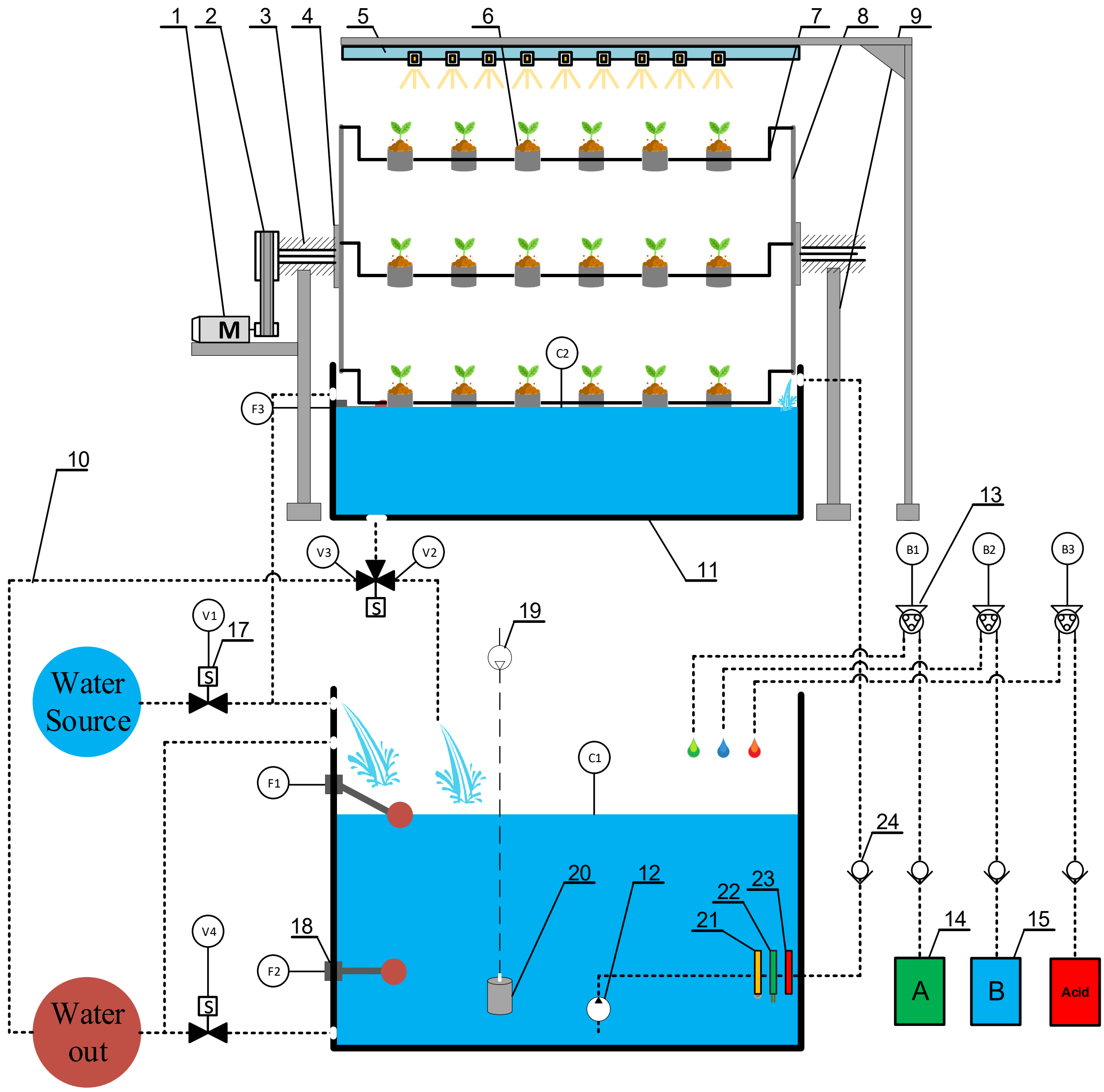

Figure 3.1 Working principle of the machine.

By using rotating mechanism of Ferris Wheel, the plant pots are taking nutrient solution and sunlight or artificial light sequentially.

Nutrients will be mixed and controlled at the storage tank C1. Therefore, the sensors will be placed in the tank. The peristaltic pump pumps chemicals from three bottles containing nutrient solutions and a pH-reducing solution to the water in tank C1.

Check valves only allow the solutions to move in a fixed direction.

Air pumps work to help nutrients dissolve faster into the solution.

The nutrient solution will be pumped into tank C2 by submersible water pumps to nourish the plant.

The float switches are responsible for controlling the water level of the two tanks.

Electromagnetic valves will be controlled to facilitate the flow of the programmed nutrient solution.

The rotary harvester contains rotating motifs, which are actuated by the motor through the belt conveyor.

By changing container C1 into a fish tank and adjusting some electrical parts, the machine shall easily become an aquaponic system to have the advantages of aquaponic technique over hydroponic one. The plants shall be fed by the waste of fish tank and then the water shall be purified by the nutrient absorption of the plants.

3.2. Mechanical calculation

The rotating frame consists of 6 pot-support bars. Since the weight of the plants on these bars varies with the growth, take the largest weight of the plant (matured) to compute.

Figure 3.2 Weight of a pot-support bar and an immature plant.

With a four-celled bar, when the plants mature, the weight of each plant is estimated to be about 0.5 kg. Therefore, the total volume of a pot-support bar when plants are mature will be about $M = 4\ kg$.

To calculate to choose motor and mechanical parts, we first consider the factor that hinders the rotation. In some cases, it is possible that the load of these pot-support bars is uneven, causing the torque to rotate. In some cases, the load is shifted sideways, with each rotating bar heavier than the other 15%. We consider 2 scenarios.

Scenario 1: Two side bars have 15% load deflection.

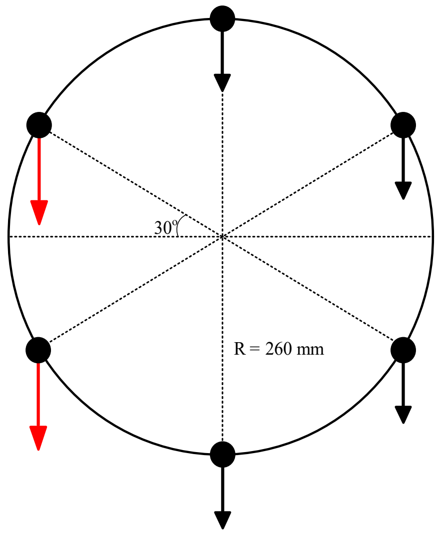

Figure 3.3 Two side bars have 15% load deflection

$$T_{load} = [2 \times (15\% \times M \times g) \times (R \times cos30°)] \times \frac{1}{\eta} \quad [3.1]$$

where, η is the belt transmission efficiency, $\eta = 95 \ldots 98\%$, chose $\eta = 95\%$. [13]

M is the weight of the pot-support bar (kg).

g gravitational acceleration (m/s^2).

$$T_{load} = 2 \times (0.15 \times 4 \times 9.81) \times \left(0.26 \times \frac{\sqrt{3}}{2}\right) \times \frac{1}{0.95} \approx 2.79\ (N \times m)$$

Scenario 2: Three side bars have 15% load deflection.

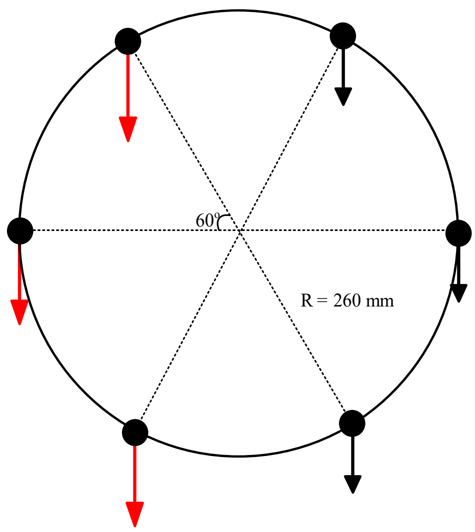

Figure 3.4 Three side bars have 15% load deflection

$$T_{load} = [2 \times (15\% \times M \times g) \times (R \times cos60°) + (15\% \times M \times g) \times R] \times \frac{1}{\eta} \quad [3.2]$$

$$= [2 \times (0.15 \times 4 \times 9.81) \times \left(0.26 \times \frac{1}{2}\right) + (0.15 \times 4 \times 9.81) \times 0.26] \times \frac{1}{0.95}$$

$$\approx 3.22\ (N \times m)$$

Besides, there is also acceleration torque of motor. Taking them into calculation which follow the instruction from Technical Reference of Oriential Motor General Catalogue [13], the needed motor power is $8.95\, W$ and needed motor torque is $57\ Kgf \times cm$. So, the chosen motor is Takanawa DS400.110/S555S.

Figure 3.5 Takanawa DS400.110/S555S motor. [14]

Motor's specification:

- Voltage: $12{\sim}24\ VDC$.
- Speed: $10{\sim}80\ RPM$.
- Torque: 20 $(Kgf \times cm)$.
- Power: $10\ W$.

So, the transmission with ratio $u = 3$ should be used to meet the required torque.

Follow the instruction of these two documents [15] [16] to calculate tranmission belt, shaft and bearings.

Diameter of small pulley and big pulley are $36\, mm$ and $108\, mm$ respectively. Distance between two centers of pulley is $218\, mm$. Module of pulleys and belt are $m = 3\, mm$. The width of belt is $12.5\, mm$ and the length is $668.8\, mm$. Through the calculation of durability checking, this belt is durable enough.

Through calculation, diameter of the shaft should be chosen to be larger than $8.79\ mm$. Bearing should be chosen followed diameter of the shaft.

3.3. Durability checking simulation

Simulation tool are used in order to test the durability of the designed shaft and support frame.

3.3.1. Durability checking of the shaft

Elastic module of steel: $[\mu] = 21 \times 10^{11}$ (N/m^2).

The load that the shaft must bear is as follows:

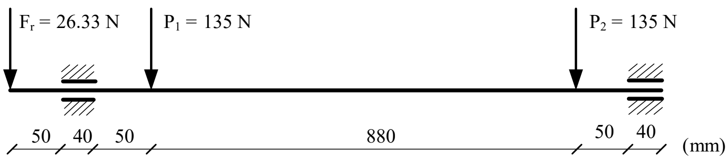

Figure 3.6 Load distribution on the shaft.

After running simulation, the obtained result is:

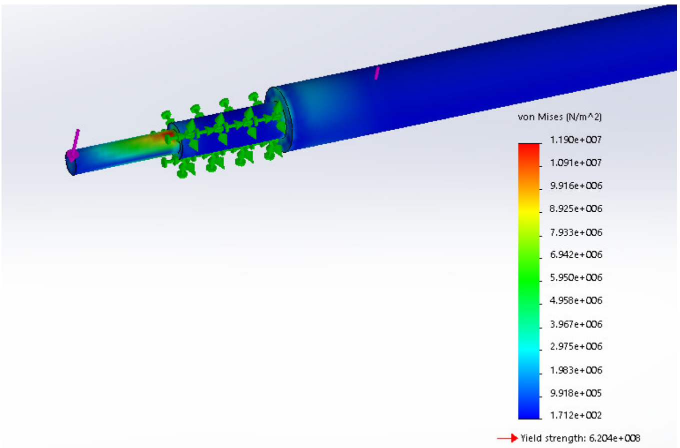

Figure 3.7 Simulation of the impact stress on the axis.

At the position of the maximum stress the shaft must bear $\mu_1 = 1.19 \times 10^7$ $(N/m^2) \leq [\mu]$. Therefore, the shaft is designed to be durable with the specified load.

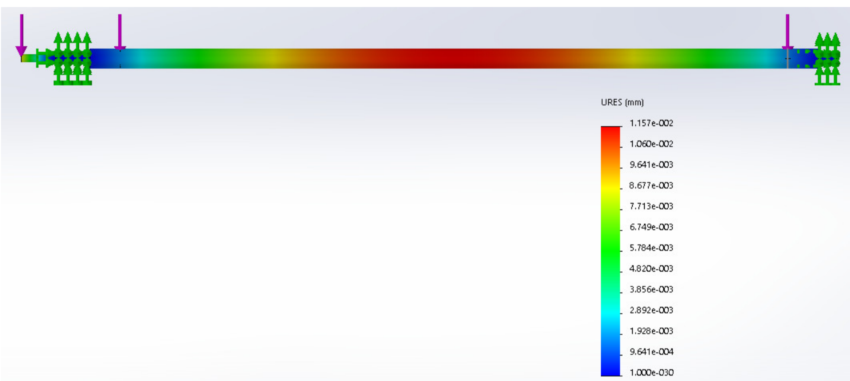

Figure 3.8 Simulation of the displacement under axial load.

The maximum displacement at the center of the shaft is only about $1.157 \times 10^{-2}\ mm$, which is very small.

3.3.2. Durability checking of the support frame

The load acting on two support frames is the mass of the entire rotating frame and shaft. The measured volume is 29 (kg). After simulation, the obtained result is:

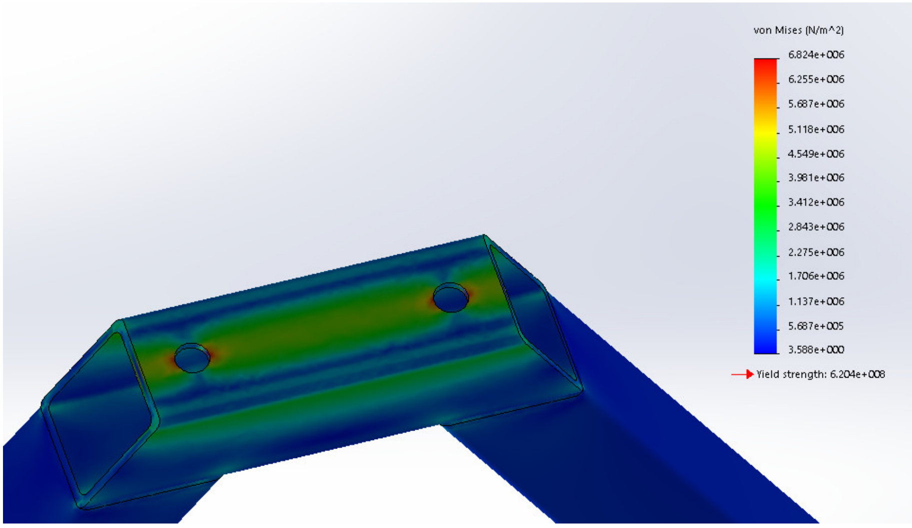

Figure 3.9 Simulation of the impact stress on one support frame.

At the position of the maximum stress the frame must bear $\mu_1 = 6.824 \times 10^6$ (N/m^2) $\leq [\mu]$. Therefore, the frame is durable with the proposed load.

CHAPTER 4: DESIGN OF CONTROL MODULE

4.1. Electrical diagram

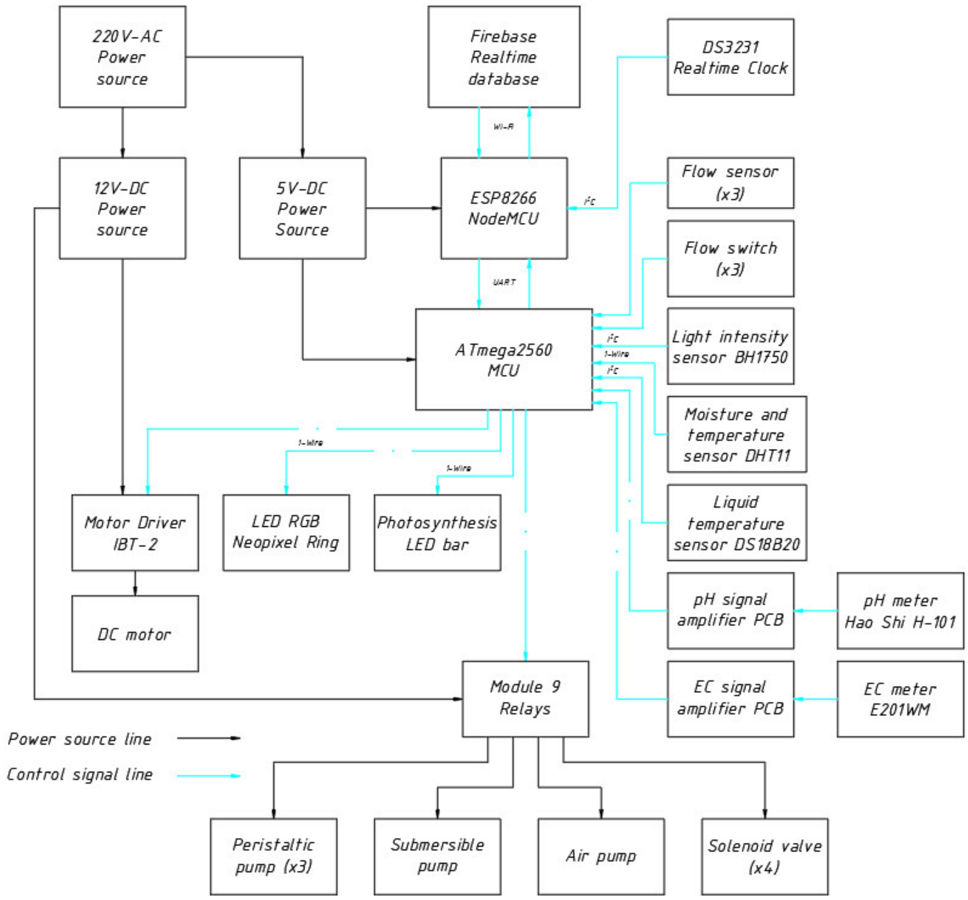

Figure 4.1 Block diagram of electrical connection

ATmega2560 acts as the central microcontroller, performs control commands, processes information from the sensor. At the same time, the ATmega2560 communicates with the ESP8266 NodeMCU via UART, NodeMCU is responsible for retrieving and sending information from the online database via Wi-Fi connection. In addition, NodeMCU receives control commands from the database to send to the ATmega2560. Sensors send measurement data to ATmega2560, which are then sent via NodeMCU to put these parameters on the database online.

Relay module for controlling the solenoid valve and the active pumps. DC motor driven by IBT-2 Driver. LEDs will turn on when the light intensity is not sufficiently brightened by the light intensity sensor. RGB LED ring acts as decoration for the system.

All those electrical parts can be easily found in the market. The sensors used in the system are discussed in more detail in the next section.

4.2. Sensors

4.2.1. Liquid temperature sensor

The temperature of the solution significantly influences the growth of the plant. In addition, the temperature changes the readings of the EC index from the probe. Therefore, the temperature sensor will also provide data to the EC sensor can offset the value changed by the temperature change. Sensors selected are sensors using the DS18B20 chip.

Figure 4.2 Waterproof temperature sensor DS18B20. [17]

Specification: [18]

- Dimesion: Length 900 mm – Wire's diameter: 4 mm.
- Working voltage range: 3 ~ 5.5 VDC.
- Accuracy: $\pm$ 0.5°C.
- Working temperature range: $-55 \sim 125$°C.
- Communication interface: 1-Wire (TTL type).

4.2.2. EC meter

Due to the application of EC water immersion probe and continuous data acquisition. Therefore, the probe was chosen as the industry-standard E201WM Conductivity Probe from ShowRange, China.

Figure 4.3 E201WM Conductivity Probe. [19]

Specifications: [19]

- Dimensions: Diameter: 14 mm, Length: 85 mm.
- Measuring range: 0 ~ 19.99 mS/cm.
- Resolution: 0.1 mS.
- Accuracy: $\pm$ 1.5%.
- Connection interface: BNC
- Operating Temperature: 0 ~ 50 ℃.

In order to obtain a sinusoidal signal source for the operation of the sensor, we need circuit that converts the DC signal into a sinusoidal signal. This circuit includes the Oscillator IC4060BM, Opamp TL034CD and the Voltage Regulator IC LM2660M.

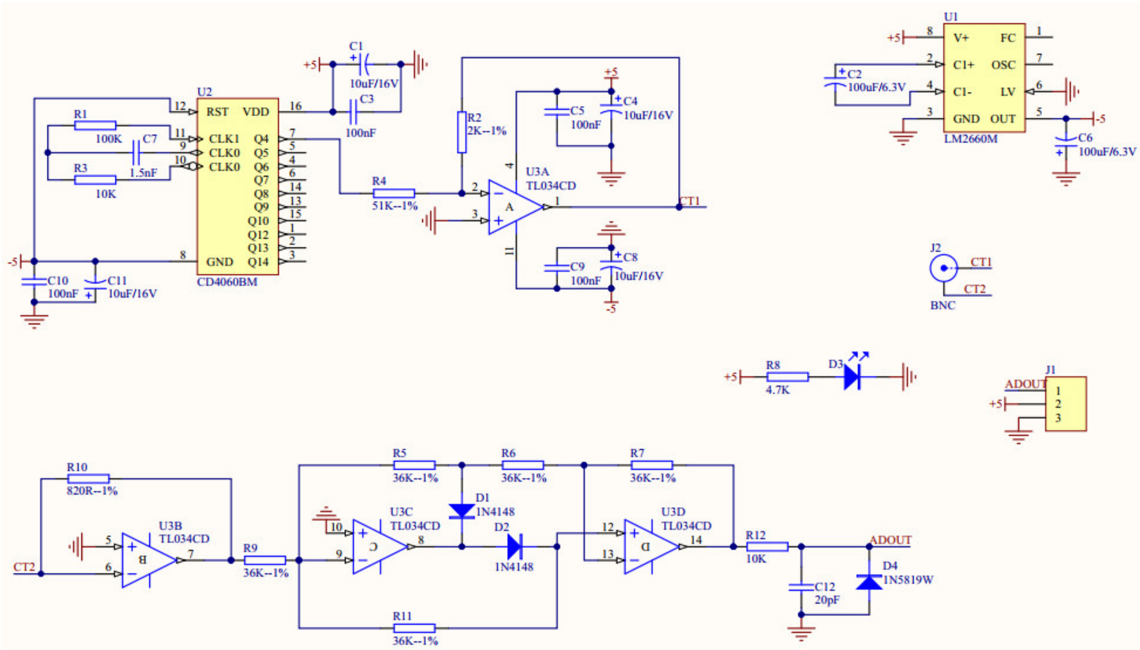

Figure 4.4 Schematic layout of the circuit. [20]

4.2.2.1. Calibration of EC meter

In order to carry out calibration for the EC meter, it is necessary to prepare two standard EC solutions. Two selected solutions are 12.88 mS/cm and 1.413 mS/cm.

Figure 4.5 Standard EC solutions. [21]

The EC meter calibration process is carried out in the following order:

Step 1: Rinse the probe with distilled water and dry it with a tissue.

Step 2: Apply standard solution for room temperature (25 ℃).

Step3: Place the probe into the first solution (1.413 mS/cm). Read the mean voltage value, considered as V1. Get points 1 (X1, Y1) = (V1, 14.13).

Step 4: Remove the probe, rinse with distilled water and dry with a paper towel.

Step 5: Place the probe into the second solution (12.88 mS/cm). Read the mean voltage value, considered as V2. Get points 2 (X2, Y2) = (V2, 12.88).

Step 6: Remove the probe, rinse it with distilled water and dry it with a tissue.

Step 7: With the two points we just measured, they can be graphed as a linear line, but they can be floated away from the origin (Figure 4.9).

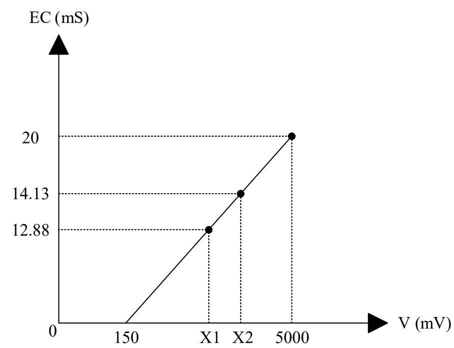

Figure 4.6

Step 8: From there, we calculate the drift as well as the slope coefficient of the linear line and infer the formula that has been calibrated.

4.2.2.2. Temperature compensation of EC meter

The EC is measured at a standard temperature of 25 ℃. The change in solution temperature changes the EC index value. Therefore, the measured value returned must be recalculated through a formula to ensure the accuracy of the measurement results.

The formula for calculating the EC formula in the solution is: [22]

$$C_{25} = \frac{C_t}{1 + \alpha(t - 25)} \qquad [4.1]$$

where,

C_{25} is the EC index calculated at 25 ℃.

C_t is the EC sensor value measured at temperature t.

α is the linear heat factor ($\alpha = 0 \sim 0.05$). For aquaculture medium ($5.5 < pH < 6.8$), $\alpha = 0.02$.

t is the temperature of solution at the time of measurement. This temperature value is measured from the DS18B20 temperature sensor described above.

4.2.3. pH meter

For convenience in reading values, the pH sensor used is an electrochemical sensor using a measuring electrode and a reference electrode to detect changes in pH values. Due to the application of pH probe in water and continuous data. Therefore, select the pH probe according to industry standard H-101, Hao Shi, China.

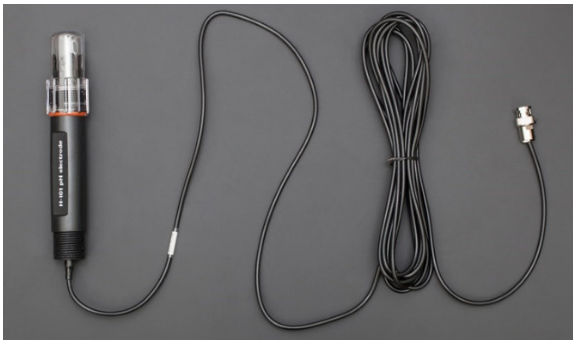

Figure 4.7 Industry standard pH probe Hao Shi H-101. [23]

Specifications: [23]

- Dimension: Length: 17.7 cm, Diameter: 2.74 cm.
- Connection interface：BNC.
- Measure range: 0 – 14 pH.
- Accuracy: ≤ 0.1 pH (tại 25 ℃).
- Working temperature range: 0 – 60℃.
- Response time: 10 s.

This type of pH probe has very low output voltage (MCU or VOM are not readable). Therefore, there should be an accompanying amplifier circuit. The circuit uses two opampa CA3140AMZ, one opamp TL81BCDG4 and switching voltage regulators TC1121COA. (Figure 4.8).

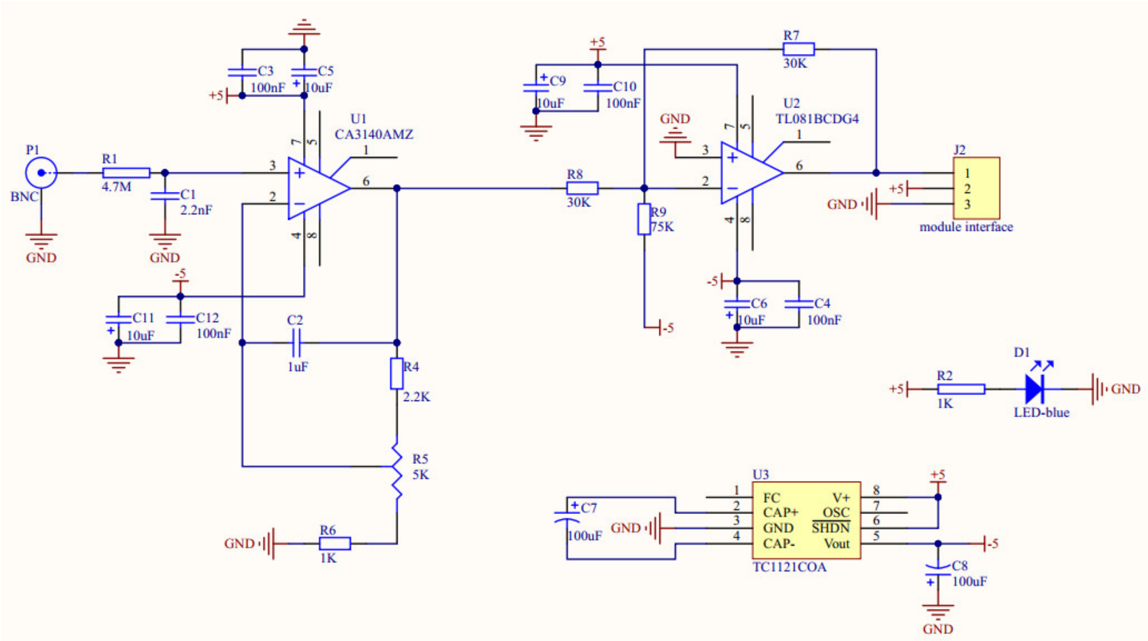

Figure 4.8 Schematic layout of the circuit. [24]

4.2.3.1. Calibration of pH meter

Figure 4.9 Standard pH solutions.

Like the calibration of EC meter, it is necessary to prepare two standard pH solutions. For hydroponic farming technique, the pH value will be controlled from 5.5 to 6.8. Therefore, the calibration using two standard pH solutions 4.01 and 7 will gave more accurate measurement results [25].

The pH probe calibration is in the following sequence: [26]

Step 1: Rinse the probe with distilled water and dry it with a tissue.

Step 2: Apply standard solution for room temperature (25 ℃).

Step 3: Place the probe into the first solution (pH 7). Read the mean voltage value, considered as V1. Get points 1 (X1, Y1) = (V1, 7).

Step 4: Remove the probe, rinse it off with distilled water and dry it with a tissue.

Step 5: Place the probe into the second solution (pH 4.01). Read the mean voltage value, considered as V2. Get points 2 (X2, Y2) = (V2, 4.01).

Step 6: Remove the probe, rinse it with distilled water and dry it with a tissue.

Step 7: With the two points we just measured, they can be graphed as a linear line but can be drifted out of the origin. (Figure 4.10)

Step 8: From there, we calculate the drift as well as the slope coefficient of the linear line and infer the formula that has been calibrated.

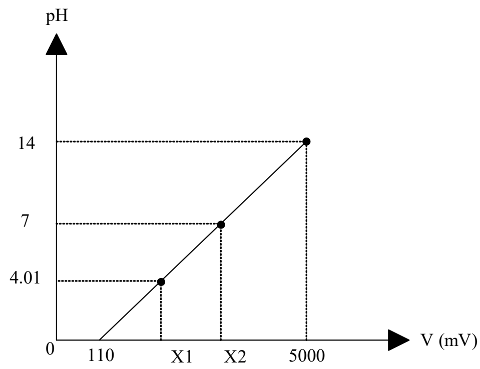

Figure 4.10

4.2.3.2. Temperature compensation of pH meter

Similar to the EC index, the pH indicator is measured at a standard temperature of 25 °C. The change in temperature of the solution also changes the pH measured in the solution. However, by measuring, the change in temperature does not change too much the return voltage value as shown in Figure 4.11.

pH	mV (0° C)	mV (25° C)	mV (50° C)
0	379	414	449
1	325	355	385
2	271	296	321
3	217	237	256
4	163	177	192
5	108	118	128
6	54	59	64
7	0	0	0
8	-54	-59	-64
9	-108	-118	-128
10	-163	-177	-192
11	-217	-237	-256
12	-271	-296	-321
13	-325	-355	-385
14	-379	-414	-449

Figure 4.11 Voltage returns and pH values at different temperatures [27]

At the same time, the change in temperature of the hydroponic medium is not too large (30 ± 10 °C). Therefore, the pH value returned by the sensor does not need to go through the heat calculation step.

4.2.4. Moisture and temperature sensor

To monitor the state of the environment around the system. Using the moisture and temperature DHT11 of Aosong, China [28].

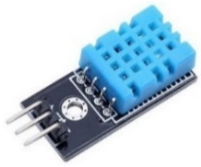

Figure 4.12 Moisture and temperature DHT11.

Specifications: [28]

- Working voltage: 5 VDC.
- Communication interface: 1-Wire, TTL.
- Moisture measurement range: $20 \sim 80\% \pm 5\%$.
- Temperature measurement range: $0 \sim 50°\mathrm{C} \pm 2°\mathrm{C}$.
- Sampling time: 1 Hz.

4.2.5. Light intensity sensor

To be able to tell whether light is enough to help photosynthesis. Using ROHM Semiconductor's BH1750 light sensor, Japan [29]. The sensor is used to measure the light intensity in lux units, the sensor has internal ADC and preprocessor so the value to be output is the direct value of the lux light intensity without having to go through any process. or calculated through I^2C communication. When the sun's light intensity is lower than the required level, the dedicated aquarium LED will be turned on to provide additional light to the plant.

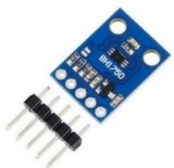

Figure 4.13 ROHM Semiconductor's BH1750 light sensor

Specification: [29]

- Working voltage: $3.3 \sim 5$ VDC.
- Commnunication interface: I^2C.
- Measurement range: $1 \sim 65535$ lux.

CHAPTER 5: APLLICATION OF IOT TECHNOLOGY

5.1. Contol of EC index

In order to know exactly the volume of nutrient solution to be mixed to reach the desired EC index, we need to make the calculation using the following formula: [30]

$$(EC_A + EC_B)V_1 + EC_2V_2 = EC_3(V_1 + V_2) \quad [5.1]$$

where,

EC_A and EC_B are the EC index of nutrient solution A and B respectively.

EC_2 is the EC index of the current solution in the container.

EC_3 is EC index after mixing the nutrient solution into the tank, also the EC index should be achieved.

V_1 is the volume of nutrient solution A and B in the container.

V_2 is the volume of solution present in the container.

The formula for volume of nutrient solutions should be added to the container:

$$V_1 = \frac{V_2(EC_3 - EC_2)}{EC_A + EC_B - EC_3} \quad [5.2]$$

5.2. Control of pH index

In order to know precisely the volume of the low concentration acid solution required for mixing, to reduce the pH index and achieve the desired pH, we need to do the following calculation: [31]

$$M_1V_1 + M_2V_2 = M_3(V_1 + V_2) \quad [5.3]$$

with $M = 10^{-pH}$ is molarity [H+] inside solution (mol/L). Where,

M_1 is the molarity of [H +] ion of acid solution used to reduce pH.

M_2 is the molarity of [H +] ion of the current solution in the container.

M_3 is the molarity of [H +] ion after mixing the acid solution into the container, also the molarity of [H +] ion is needed.

The formula for volume of pH down solution should be added to the container:

$$V_1 = \frac{V_2(M_3 - M_2)}{M_1 - M_3} \qquad [5.4]$$

5.3. Application for mobile platform

For the convenience of storing measurement data from sensors as well as control commands, the system utilizes the real-time online Firebase Realtime Database, developed and supported by Google (United States) [32].

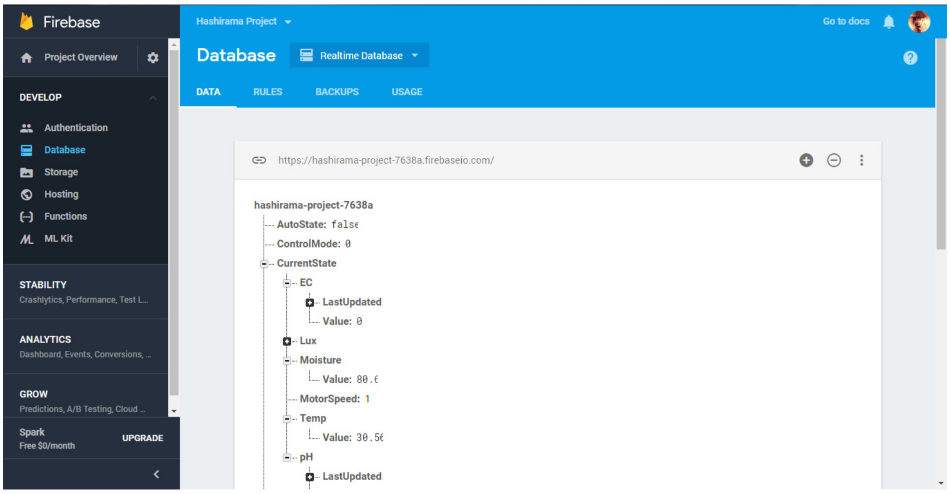

Figure 5.1 JSON tree data management interface of the machine.

Firebase's data management architecture is a JSON tree, making it easier to access the data than traditional tables. In addition, when the values of a branch in the JSON tree change, the system is able to immediately identify this change, thereby creating real-time data center responsiveness.

With the remarkable advantages of developing and extending the future application of Android Studio, this tool was chosen to develop a mobile application that monitors and controls the hydroponics system itself. motion. The chosen programming language is Java. The graphic design language chosen is Material Design.

After the design of the user interface and functional programming, the first version of the application was formed. The application requires users to have an Internet connection to access the Firebase real-time data axis. At this point, users will be able to monitor the parameters and control the equipment of the system in real time. You can also view images from the camera (if integrated) of the system. When a user has no Internet connection, only the old parameters stored in the mobile device's cache will be displayed.

Before using, users need to sign up for an account to access the online data center. That data center will be linked to an automated hydroponic system.

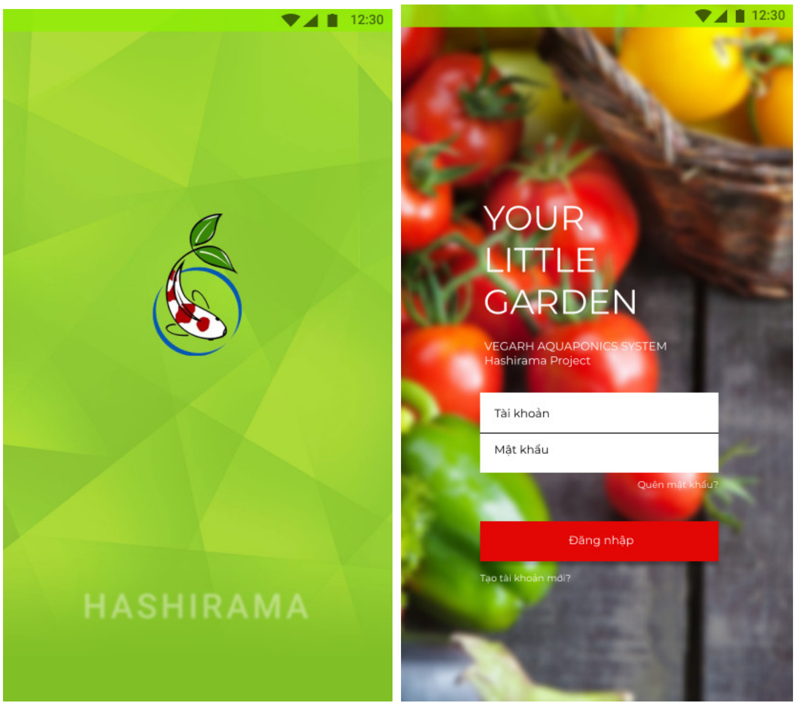

Figure 5.2 Interface of splashscreen and account login.

After successful login, the user will be taken to the control panel, which contains the functions of the application. The user selects which function to use and the interface on the phone switches to the interface for that function.

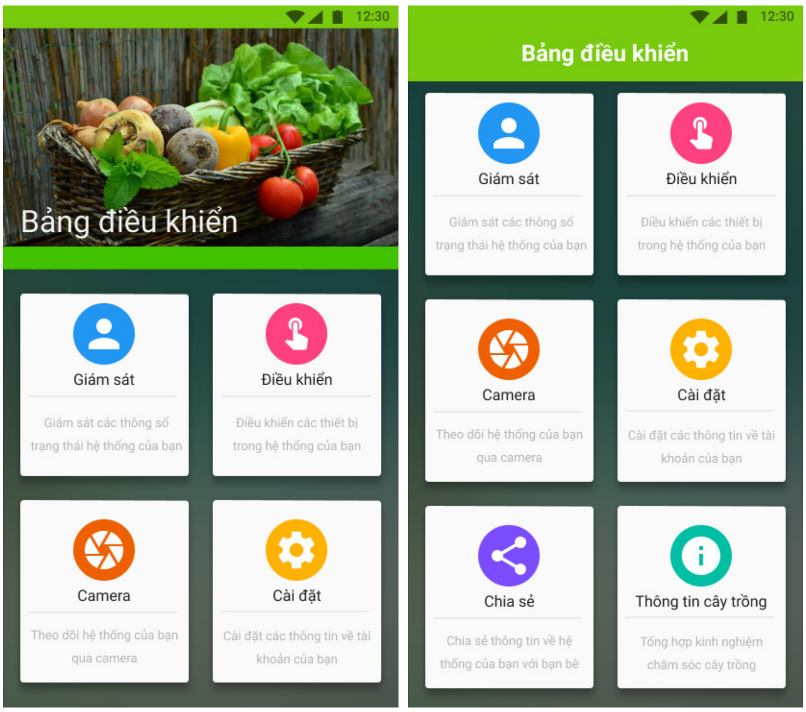

Figure 5.3 Dashboard interface to select the function.

The monitoring function will display the current index of the system and graph the change of these indicators during planting.

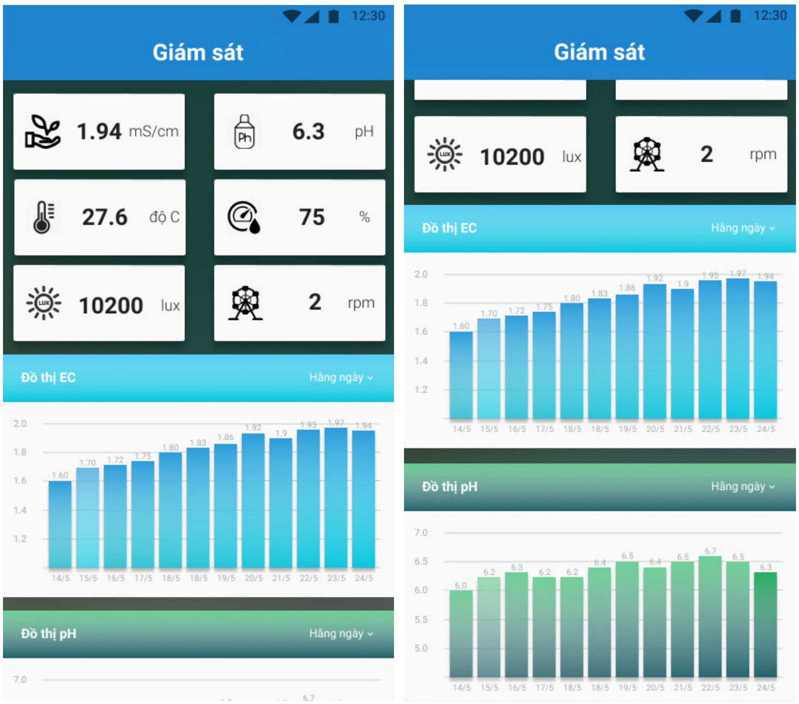

Figure 5.4 Interface for monitoring parameters of the system.

The camera control and view function have the interface shown in Figure 5.5.

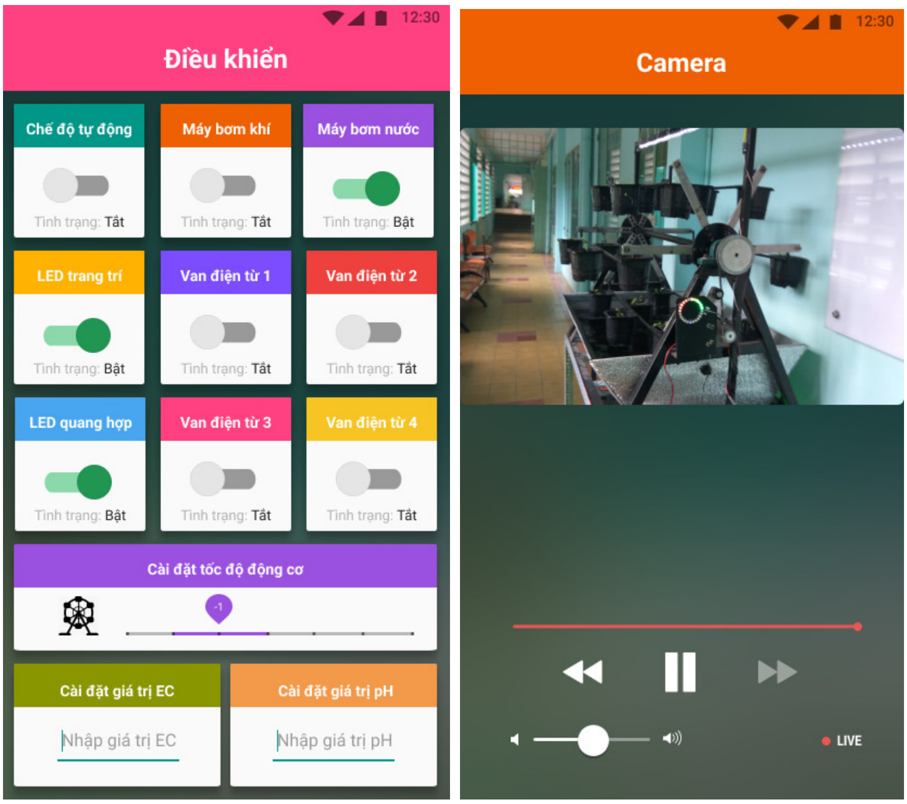

Figure 5.5 Interface to controls the device and camera observation functions.

CHAPTER 6: EXPERIMENTAL VERIFICATION

6.1. Prototype development

In order to reduce the change in temperature due to the absorption of light from the water, the upper tank is coated with a layer of insulating material.

Figure 6.1 Prototype of the machine.

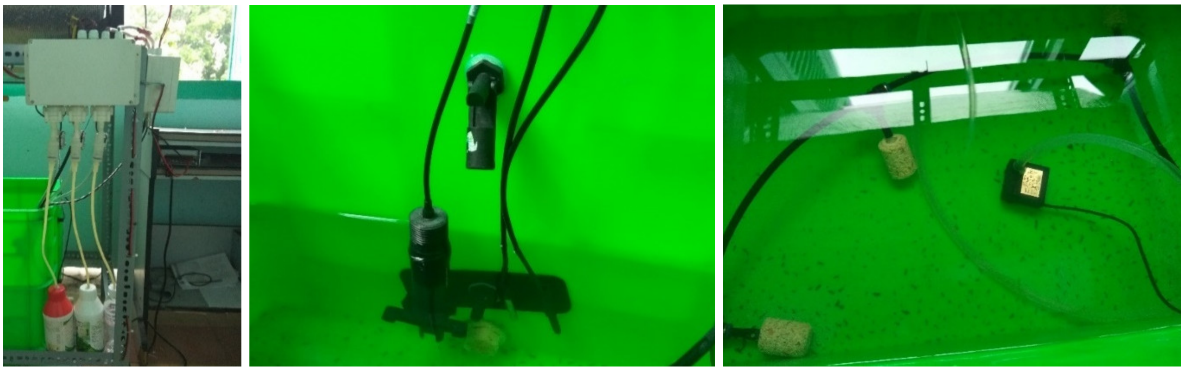

Figure 6.2 Electrical parts and sensors of the machine.

6.2. Experimental results

Sowing to seedlings begins on May 10, 2015. The experimental model was completed on May 14, 1818, the seedlings also began to be put on the truss rotation on this day.

The cultivated variety includes red jute mallow (TN-855) (Corchorus olitorius L). Soak seeds in warm water (40 ~ 50 °C) for 15 minutes, remove the floating seeds (damaged seeds). Then place the seeds in the baskets, under a coconut shell (2cm), put back, press lightly. Wet for the groom. After 1 ~ 4 days, seeds will germinate into young trees. At this time, start moving the gantry on the truss.

Table 6.1 Growth parameters of red jute mallow varieties.

	Sprout	**Growing plant**	**Growth nutrients**
Time	1~4 days	20~25 days	Remaining
EC		1.5~2.0 mS/cm	1.7~2.5 mS/cm
pH	6.0~6.7	6.0~6.7	6.0~6.7
Temperature	25~29℃	18~25℃	20~25℃

The EC index, pH and average daily temperature are monitored and recorded from May 14 to May 31 (18 days) and are shown in the following table:

Table 6.2 Parameters recorded during growth.

Time	**EC** (mS/cm)	**pH**	**Temperature** (℃)
5/14/2018	1.60	6.0	27.3
5/15/2018	1.70	6.2	26.8
5/16/2018	1.72	6.3	27.5
5/17/2018	1.75	6.2	28.6
5/18/2018	1.80	6.2	27.4
5/19/2018	1.86	6.4	26.5
5/20/2018	1.92	6.5	27.6
5/21/2018	1.90	6.4	26.3
5/22/2018	1.95	6.5	27.2
5/23/2018	1.97	6.7	27.8
5/24/2018	1.94	6.5	28.2
5/25/2018	1.92	6.3	27.5
5/26/2018	1.88	6.4	26.8
5/27/2018	1.90	6.2	25.8
5/28/2018	1.85	6.2	27.3
5/29/2018	1.87	6.4	27.9
5/30/2018	1.92	6.6	27.7
5/31/2018	1.86	6.7	28.2

The red jute mallow plants before being put on trusses 3 to 4 cm tall.

Figure 6.3 Sprout before being put on the pot-support.

Jute vegetables grown after more than two weeks have grown to 15 cm high and have a trunk diameter of about $3 \sim 4\ mm$.

Figure 6.4 Individual trees during growth and development.

CHAPTER 7: CONCLUSION AND FUTURE WORK

7.1. Contributions

The machine works fine, although the latency due to the wifi connection depends on the stability of the network. In practice, the time from the moment the button is pressed to the system's execution time is about $1.2 \sim 2.1\ s$.

The results are achieved: rotating the truss continuously, switching off all applications on the system and measuring the readings of the EC index, pH, temperature of the nutrient solution is mixed. These values are stored on the data center and are displayed graphically on the application.

In the process of processing, the iron frame is machined quite hard and hard, there are times when 6G welding (the most difficult type in welding because there is no fulcrum).

7.2. Futrue work

Redesign the iron frame to easily center and avoid excessive welding, causing material deformation.

For real products to be used in home decor, the machine need industrial designs. Toward development to become a complete aquaponics system.

Planting and recording data with more varieties to test the success of the system, along with the care process is adjusted to suit each plant.

With data on nutrient solution indicators and environmental indicators such as temperature, humidity, light intensity collected over time, along with indicators of plant growth that can be measured It is possible to use them as a template for machine learning in order to have It is possible to have better planting processes in later times. During the Google I / O 2018 event, the Firebase Online Data Center introduced the ML Kits (Machine Learning Kits) tool that supports data center applications that can easily use its data for Machine learning algorithms that this tool builds on [33]. With the data stored on the data center, this is an advantage that can be utilized in the future.

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