SMART AQUAPONICS IN A TEMPERATURE-CONTROLLED GREENHOUSE WITH PLANT GROWTH MONITORING SYSTEM USING RASPBERRY PI VIA ANDROID IOT APPLICATION

A Project Study Presented to the Faculty of

Electronics Engineering Department

College of Engineering

Technological University of the Philippines

In Partial Fulfilment of the Course Requirements for the Degree of

Bachelor of Science in Electronics Engineering

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APPROVAL SHEET

This Project Study entitled **"SMART AQUAPONICS IN A TEMPERATURE-CONTROLLED GREENHOUSE WITH PLANT GROWTH MONITORING SYSTEM USING RASPBERRY PI VIA ANDROID IOT APPLICATION"** has been prepared and submitted by the following proponents:

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ABSTRACT

Among the main concerns in inefficient agricultural methodology involves critical food safety from weather instability, environmental degradation caused by waste from conventional farming, wasteful energy usage, and climate change. To give response to these, the paper introduced the development of a self-sustained smart aquaponics system in a temperature-controlled greenhouse made with Android IoT monitoring and automatic correction. The smart aquaponics contains plant growth monitoring system that measures plant surface area through image processing using Raspberry Pi. It also involves the acquiring of real time data detected by the light intensity sensor, and air temperature sensor. It includes the monitoring of the pH level, and temperature of the recirculating water of the system. If the acquired data is not within the threshold range, the correcting devices, namely grow lights, exhaust and inlet fans, evaporative cooler, aerator, and peristaltic buffer device were automatically triggered by the system to correct, and achieve its normal status. The internet remote access includes the effective wireless transmission and reception of data report between the system and an Android unit with the Android application in real-time. The study focused on the evaluation of two experimental set-ups, the conventional soil-based farming and the smart aquaponics system, comparing the plant growth in terms of surface area of lettuce, mustasa and pechay. Historical data comparison from a previous study was applied for the fish growth in terms of length and weight of tilapia. After data gathering and statistical analysis, results showed that the smart aquaponics set-up successfully produced a yield better than the conventional farming set-up and the said previous study.

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CHAPTER 1

THE PROBLEM AND ITS SETTING

This chapter presents the background of the study, the statement of the problem, the objectives, the significance, the scope and the limitations of the study.

1.1 Introduction

In this day and age, effects of inefficient agricultural methodology such as environmental degradation caused by waste from conventional farming, disruption of food supplies from weather volatility, wasteful energy usage, and limited livelihood opportunities for communities seek innovative, sustainable, and economically viable solutions. As a response to these problems, aquaponics is the combination of aquaculture, breeding and raising of aquatic organisms such as fish, shrimps, crabs in a controlled environment; and hydroponics, production of plant in a soilless medium, in a mutually beneficial environment. In a recirculating aquaculture, nutrients, which are wastes eliminated directly by the fish or produced by the microbial breakdown of organic wastes, are absorbed by the plants cultivated hydroponically (Rakocy, Bailey, Shultz, & Thoman, 2004). Aquaponics gives more security on food loss, more productivity in relation to its cost, and more accessibility as it can be placed on urban areas. It paves a great way when it comes to business wherein it produces fishes and crops that is fresh, organic, and profitable in the market. Although different studies about aquaponics have improved locally and internationally, most of them are having problems such as lack of constant monitoring of the sensing system with corresponding correcting devices, insufficient information to the aquaponics enthusiast on status of the plants' growth, unsuitable climate for specific crops that needs lower temperature requirements, and destructive methods of measuring plants. Normally, traditional direct measurement methods are easier but takes a lot of time and damaging to plants. As an important problem to be answered in plant studies, the plant feature measurement has beneficial applications especially in plant growth modelling and climate control in greenhouses. (Yu-Hui, et al., 2013)

As a solution to the problems stated, the researchers propose a smart aquaponics in a temperature-controlled greenhouse with plant growth monitoring system using Raspberry Pi via android Iot application to automate the plant growth measurement process while controlling the temperature and several environmental parameter of the aquaponics system.

1.2 Background of the Study

In sustaining a potential aquaponics system, one of the aspects to guarantee high crop production is the crop growth monitoring aside from tracking, correcting, and managing of the vital parameters of the water recirculating in an aquaponics system. According to *An Automatic Vision-Based Plant Growth Measurement System for Leafy Vegetables* (Yu-Hui, et al., 2013), the information related to plant features is especially convenient for its uses in climate control and plant growth modelling in greenhouses or plant factory. Traditional direct measurement methods are generally simple and reliable, but takes much labor and also time consuming. In contrast, vision-based methods are non-destructive and efficient methods to describe exterior plant features and plant growth. According to *Optimization of a Backyard Aquaponic Food Production System* (Connolly & Trebic, 2010), temperature, dissolved oxygen concentrations and pH level are the most critical water quality factors to be considered and monitored continuously. Other studies such as *Economic Feasibility of Aquaponics in Arkansas* (English, 2015) have shown that in hydroponic growing conditions, the air temperature may exhibit a wider range than traditional farming methods will allow. Alternately, researchers with the Alabama Cooperative Extension System, found that the water within the aquaponics system should be maintained at 24 °C with an allowable air temperature range of 13-32 °C, in order to achieve optimal fish, bacterial and plant growth. Climatic conditions, particularly temperature and light intensity, have a solid effect on the yield and growth, but also on nourishing value of crops according to *Hydroponic Production of Vegetable and Ornamentals* (Savvas & Passam, 2002). Lastly, the study *Design of a Smart Monitoring and Control System for Aquaponics Based on OpenWrt* (Wang, Zhao, Huang, & Xu, 2015) demonstrated the application of the IoT (Internet of Things) to aquaponics, which is linked with social platforms for interaction and transmission of data parameters via internet. The concepts stated contribute to developing an aquaponics system that is stimulated to solve the restriction and problems of previous aquaponics researches.

This study shall be composed of the expanded aquaponics setup, use of Ion-Sensitive Field Effect Transistor (ISFET) as a pH sensor, vision-based plant growth monitoring using image processing, detection of additional environmental parameters specifically, light intensity, air temperature, and water temperature.

1.3 Statement of the Problem

The proponents of the project study sought answers to the following questions:

1. How will the Raspberry Pi acquire and process images of the plants from the camera?

2. How to monitor and correct the light intensity and temperature in the greenhouse?

3. How to store all the acquired data from the yield growth monitoring system and from the aquaponics parameter sensors?

4. How to interface the plant growth monitoring system and the monitoring and correcting system to the smartphone via remote internet access?

1.4 Objective of the Study

1.4.1 General Objective

This study aims to develop a temperature-controlled greenhouse and plant growth monitoring system of smart aquaponics through Android IoT application.

1.4.2 Specific Objectives

The study aims to meet the following goals needed for the development temperature-controlled greenhouse and plant growth monitoring system of smart aquaponics through Android IoT application.

1. To develop a Python program on Raspberry Pi that processes the acquired images from the camera to monitor and assess the plant based on surface area using image processing.

2. To design a circuit that monitors light intensity and air temperature, and automatically corrects illumination for plants using grow lights and the

temperature through an air cooling and ventilation system of the greenhouse, respectively.

3. To create a database using TinyWebDB that stores the acquired data from the plant growth monitoring system and the aquaponics parameter sensors.
4. To develop a Graphical User Interface for Android smartphone using MIT App Inventor programming for the supervision of plant growth, and the system's real-time status.
5. To establish connection between the Android application and the aquaponics system via an IoT gateway.

1.5 Significance of the Study

The study is a self-sustainable smart aquaponics system that will use solar power, hence lessens the electrical consumption while securing food in urban zones that has minimal space and increasing the sustainability. The system will utilize recirculating water and soilless medium, therefore minimizes use of water resources, disregards the demand of chemical fertilizers, and guarantees high-yields of fresh, purely organic, nutritious, and easy to harvest. High-end crops grown in the system can stand in varying temperature and climate. The implementation of plant growth monitoring system shall eliminate the problems regarding traditional contact method of measuring that may lead to destruction of plants. Maintaining a temperature suitable for cold season crops solves the unsuitability of growing these crops on a warm urban area. On Android application of a common smartphone, the water parameter readings, specifically, pH value, water temperature, light intensity, and air temperature readings as well as the data from the growth measurement of plants will be displayed that allow the urban farmers to remotely monitor their aquaponics system through Internet of Things gateway.

1.6 Scope and Limitations

The research study will focus on the development of smart aquaponics system through Android IoT application with a plant growth monitoring system and temperature-controlled greenhouse. It includes the monitoring of the pH level and temperature of the recirculating water of the system. The pH level and temperature are provided with a correcting system through the automatic buffer device and aerator, correspondingly. The aerator will also be used to supply the dissolved oxygen. The automatic fish feeder shall will be used for smart feeding purposes. Solar power technology incorporated to the system shall sustain the system's need for reduced electric consumption. The study also includes the monitoring of the light intensity, and temperature inside the greenhouse. LED grow lights, and evaporative air coolers and fans will be used as correcting device to the illumination of plants and the air temperature of the greenhouse. The study is limited to the measurement of estimated surface area of the plants by top view image capturing with the use of Raspberry Pi, camera and a Python Program. In order to monitor the plants, the entire planting beds shall be captured repeatedly every week. However, the measuring doesn't include the height, length and width of the plants.

The study is limited to culturing vegetables, namely, Pak Choi (Brassica rapa / Pechay Tagalog), Lettuce (Lactuca sativa / Letsugas) and Mustard Greens (Brassica integrifolia / Mustasa). While in aquaculture set-up, the study is limited to culturing Nile Tilapia (Oreochromis niloticus).

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 Conceptual Literature

2.1.1 Aquaponics

Aquaponics is the integration of aquaculture, the farming of fish and aquatic organism, and hydroponics, the growing plants without water. The aquaponics set-up permits a healthy symbiotic connection among the three living groups present, the fish, plants and bacteria. The plants are fed with the essential nutrients that is produced from the fishes' wastes, and the plants clean the water that goes back to the fishes at the same time. The bacteria from the fish waste present in the water converts ammonia into nitrate that the plants can use to grow. The result is a perfect association between aquaculture and gardening.

Small private, educational/research aquaponics systems have been constructed in numerous places globally and the technology is becoming progressively famous. There is rising interest in industry to experiment whether the technology can be profitable business to run in large-scale systems, raising plants and fish instantaneously for the market. (North, 2016)

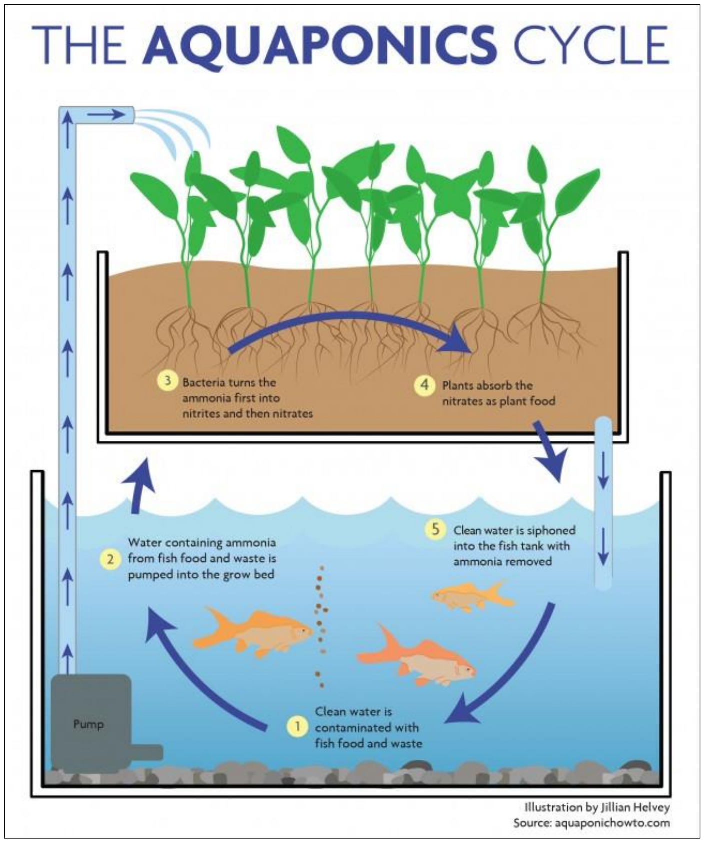


Figure 2.1 Aquaponics Cycle

(Aquaponics How To, 2009)

2.1.1.1 pH in Aquaponics

The tolerable range for fish is commonly between pH 6.5 to pH 9.0. Ammonium is changed into toxic ammonia when water is very alkaline (> pH 9) results to fish kill. Acidic water (< pH 5) depletes metal rocks and sediments which can badly affect fishes' metabolism and be fatal. The guidelines for warm water fishes recommends: pH < 4 is fatal acid point; pH 4.0 - 5.0 means no production; pH 6.5 - 9.0 implies necessarily for fish growth; pH 9.0 - 11.0 results to decreasing growth rate; and pH > 11.0 is the fatal alkaline point.

Usually, ideal pH value for fish growth does not match with the ideal pH for plant growth where plants prefer pH < 6.5. Hence, the ideal pH value for aquaponics ranges frequently in the middle of pH 6.8 and pH 7.0. Calcium carbonate, potassium hydroxide and calcium hydroxide are bases that may be added to the system in order to increase the pH value and preserve the pH adjacent to neutral pH 7.0. With at least once per week or more regularly, pH level needs to be observed frequently. Daily monitoring is recommended as pH usually declines on a time scale of one day as a outcome of nitrification and respiration. Nitrification takes the aquaponics system to become acidic. Also, fish respiration upturns CO_2 levels in the water resulting to lowering of pH and tends the water to be acidic. (Aquaponics Guideliness, 2015)

A pH level lower than 6 is intolerable for nitrifying bacteria as their ability to transform ammonia into nitrate reduces in low pH or acidic states. This results to low rate of biofiltration wherein bacteria struggles in transforming ammonia to nitrate leading to rise of Ammonia and a fatal system to fishes. (Small-scale Aquaponic Food Production Integrated Fish and Plant Farming, 2014)

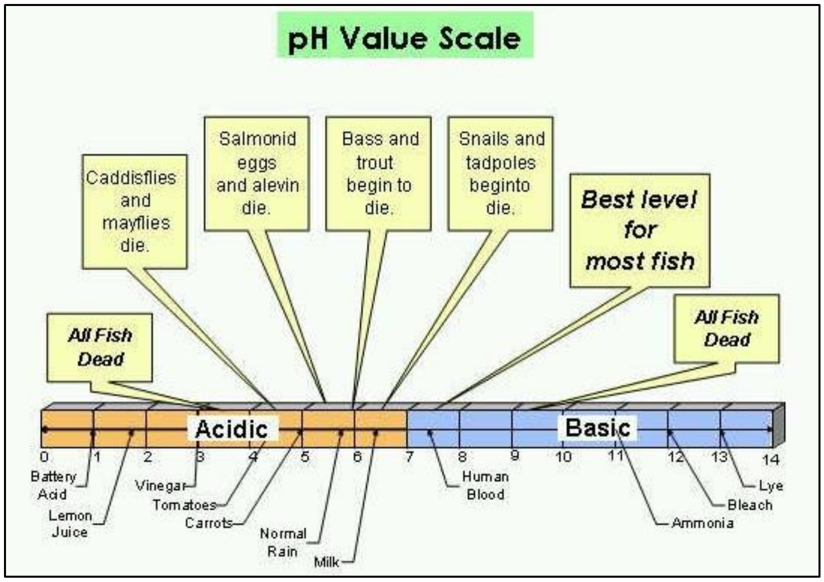


Figure 2.2 Optimal Aquaponics pH Range

(The Environmental Importance of the Different Impairment, 2011)

2.1.1.2 Buffer Solutions

Calcium carbonate, potassium hydroxide and calcium hydroxide are bases that may be added to the system in order to increase the pH value and preserve the pH adjacent to neutral pH 7.0. With at least once per week or more regularly, pH level needs to be observed frequently. (Aquaponics Guideliness, 2015)

Figure 2.3 Liquid Calcium Carbonate ($CaCO_3$) for pH Correction

(Science Company, 2017)

2.1.1.3 Temperature

Fish species are temperature-dependent. Warm water species such as goldfish, bass, catfish, and tilapia prefer temperatures ranging from 65 to 85°F (18–29°C). At a range of 55 to 65°F (13–18°C), cold water species like trout grow well. Tilapia desire temperature range of 81–85°F (27–29°C) for optimum growth. Tilapia growth decreases when water temperature goes below 70°F (21°C) and results to the stopping of reproduction. Temperatures drop below 50°F (10°C) is fatal to tilapia. With respect to Oreochromis niloticus (Nile tilapia), their vital range lays between 14-36°C. Some vegetables grow best at temperatures ranging from 70 to 75°F (21°C–24°C), and biofilters (nitrifying bacteria) perform optimally at temperatures ranging from 77 to 86°F (25°C–30°C). As with other water quality parameters, the key is to find a temperature that falls within the acceptable range for all three components of the aquaponics system. (Rossana, 2016)

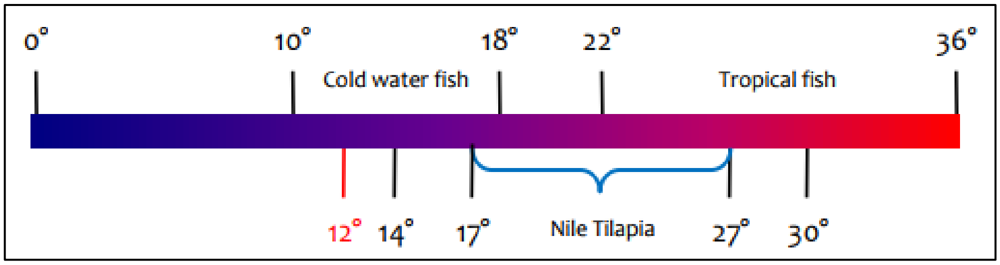


Figure 2.4 Optimal Aquaponics Temperature Range

orarinsdottir, 2015)

2.1.1.4 Tilapia

The fastest growing species usually used in aquaponics is tilapia. Tilapia is a warm-water species that grows well in a recirculating tank culture. It is resistant to shifting water conditions such as pH, and temperature. (Diver, 2006)

The tilapia is the second most significant fish cultured next to milkfish or bangus in the Philippines. The tilapia industry has achieved a 13.75% growth from 2001 to 2006. (Fisheries Policy and Economics Division, 2008) The Philippines produced 316,536 metric tons of tilapia in 2013 with a value of USD 669.8 million making the Philippines the 3rd largest tilapia producer in Asia and the 4th largest tilapia producer in the world. In particular, Nile Tilapia (Oreochromis niloticus) is the most predominant species and second most important cultured fish in the country. (Guerrero III, 2013)

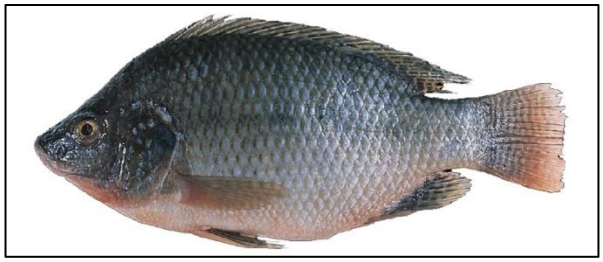


Figure 2.5 Aquaponics-cultured Tilapia

(The Basics of Breeding Tilapia for Aquaponics, 2017)

2.1.1.5 Lettuce

Lettuce is the fast growing vegetable in the aquaponics system. Generally lettuce can be harvested 40-50 days after planting. One of the best things about growing lettuce inside is that the temperatures around 78°F (26°C) are ideal for year-round growing. (Dr Kline, 2008) Lettuce is a cool-season crop. Grow lettuce in full sun or partial shade. Lettuce prefers a soil pH of 6.0 to 6.8. (Albert, How to Grow Lettuce, 2017)

Figure 2.6 Lettuce (Lactuca sativa / Letsugas**)**

(Albert, 2017)

2.1.1.6 Mustard Green

Brassica juncea, or mustard greens, is a member of the brassica family. Mustard is another crop which is easy to grow. Mustard requires 30 to 40 days to reach harvest. Its pH ideal condition ranges from 6 – 7.5 and optimum temperature is between 50 – 75°F (10 – 24°C). (Storey, 2016)

Figure 2.7 Mustard Green (Brassica juncea)

(Albert, 2017)

2.1.1.7 Pak Choi or Petsay

Pak Choi cultivates in media beds having 13-24 °C temperature and a water pH of 6-7.5. (Storey, Here's What You Need to Know About Growing Bok Choy in Hydroponics, 2016) It grows from 45-70 days. Pak Choy is temperature tolerant which makes it good to fit in many hydroponic and aquaponics systems.

Figure 2.8 Pak choi

(Herbs form Wales, 2012)

2.1.2 Sensors

Sensors are devices that detect changes in physical or electrical which produces an output as a recognition of in the quantity detected. Its output is in electrical or physical form. (Agarwal, 2015) Sensors converts physical parameters into a signal which is measured electrically. These parameters could be light, heat, motion, moisture, pressure, etc. (Sensors: Different Types of Sensors, 2012).

2.1.2.1 Ion-Sensitive Field Effect Transistor (ISFET)

The ISFET is a silicon-based potentiometric sensor device that is used to measure ion concentrations (H^+ or OH^-) in a solution which causes voltage on the gate insulator. ISFET has the same operating principle and structure with Metal Oxide Semiconductor Field-Effect Transistor or MOSFET, where ISFET has source, drain, gate insulator and, reference electrode. It is also sensitive to pH, different ions and products of enzyme reactions. (Lee, Kim, & Kim, 2009). The chemical sensitivity of the ISFET is completely controlled by the properties of electrolyte. It has fast response with simple integration of measurement electronics. ISFET can be integrated with MOSFET, and the standard transistors of integrated circuits. (Agarwal, Ion Sensitive Field-Effect Transistor – ISFET Working Principle, 2015)

Figure 2.9 Ion-Sensitive Field Effect Transistor (ISFET)
(Winsense Co., 2013)

2.1.2.2 Temperature Sensor

The DHT11 measures temperature with the NTC temperature sensor, thermistor, that is surface mounted and assembled with the unit. (Circuit Basics, 2015) With a capacitive humidity sensor and a thermistor to detect the environment air, DHT11 releases a digital signal on the data pin.

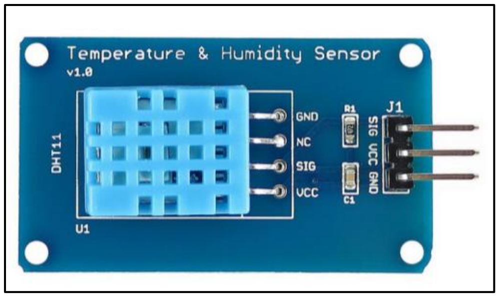


Figure 2.10 DHT11 Temperature and Humidity Sensor

(Deal Extreme, 2016)

2.1.2.3 Water Temperature Sensor

For aquaponics systems, DS18B20 digital thermometer is mostly used and is suited for this application. Under wet conditions, DS18B20 is pre-wired and waterproof that can withstand up to 125°C. Having a unique 64-bit serial code, it communicates precisely over a digital 1-wire bus that requires only one data line (and ground) to connect with a microprocessor, and can give up to 12 bits from digital-to-analog converter. (Waterproof DS18B20 Digital Temperature Sensor + Extras, 2017)

Figure 2.11 DS18B20 Temperature Sensor

(Makerlab Electronics, 2016)

2.1.2.4 Light Intensity Sensor

A light sensor is a device for measuring the intensity or brightness of light. Illuminance is a measure of how much luminous flux is spread over a given area. Luminous flux that is measured in lumens is known for a measure of the total "amount" of visible light present. The illuminance is a measure of the intensity of illumination on a surface. Light intensity sensors detects the amount of light spreading on the plants.

The sensor used in this system is a BH1750FVI light intensity sensor module with a built-in 16 bit Analog-to-Digital converter that generates a digital signal. The data from this module is given in lx (lux meter). It communicates with the microcontroller board (Arduino) through an I2C bus interface with two alternative address. The sensor has a working voltage of 3.3V~6V. It measures light intensity ranging from 1~ 65535 lx and has a 50Hz/60Hz light noise reject-function. Its spectral responsibility is approximately the same as human eye response. (Rawashdeh, 2014)

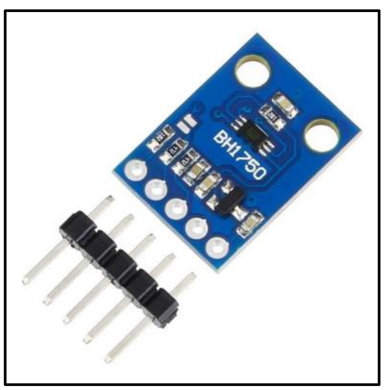


Figure 2.12 BH1750FVI Light Intensity Sensor Module

(BH1750 Light Intensity Sensor, 2017)

2.1.3 Arduino Mega 2560

The Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins where 14 can be used as PWM outputs, a 16 MHz crystal oscillator, 16 analog inputs, 4 hardware serial ports UARTs, a USB connection, a power jack, and a reset button. It is designed for project that requires more I/O lines, sketch memory, and RAM. It contains all requirements that supports the microcontroller. (Arduino, 2017)

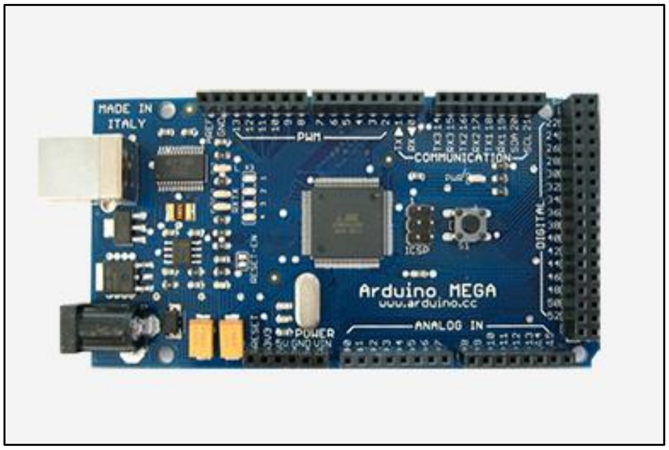


Figure 2.13 Arduino Mega2560 Board

(Arduino Mega, 2017)

2.1.4 Raspberry Pi 3

The Raspberry Pi device is a small-sized computer that appears like a motherboard with visible mounted chips and ports. It has all the components needed to connect input, output, and storage devices, such as 40 general-purpose input (gpio), 4 USB 2.0 ports, an ethernet port, micro SD card slot and HDMI video output, and offers quad-core 64-bit ARM Cortex-A53 CPU running at 1.2GHz. (Johnson, 2012)

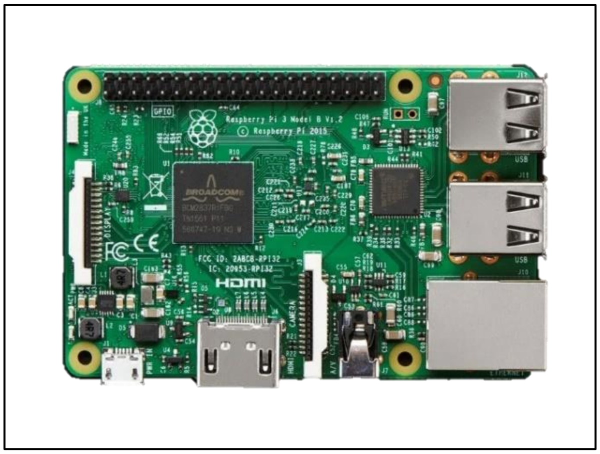


Figure 2.14 Raspberry Pi Module

(Adafruit, n.d.)

2.1.5 C Programming Language

C is called a high level, compiler language. The purpose of a high level computer language is to offer an easy way of giving a program of instructions to a computer. Without any loss of efficiency, C allows meaningful variable names and function names to be used in programs. It has a set of versatile loop constructions (for, while, do) and well-ordered methods of making decisions. These deliver an exceptional origin for directing the flow of programs. (Burgess, 1999)

2.1.6 Python

Python is an object-oriented, high-level programming language. Python is mostly considered as a scripting and automation language. Used as a replacement for batch files or shell scripts, Python is also used to automate communications with web browsers or application GUIs. Cross-platform GUI applications can be produced. Python modules and libraries are object in the Python language.

Working as a highly effective code generator, Python can write applications that manipulate own functions.

```python
# This PyOrigin example will import export all the graph pages to a PNG file.
import os
import sys
import PyOrigin

# Define a function to export all graphs in the current project.
def expAllGraphs():
    # Check how many graph pages the current project has.
    if PyOrigin.GraphPages().GetCount() > 0:
        # Loop for each graph page.
        for graph in PyOrigin.GraphPages():
            print('Exporting', graph.GetName())
        PyOrigin.XF('expGraph', {'type':'png','export':'project','overwrite':'
    else:
        print('There are no graphs to export.')


if __name__ == '__main__':
    if len(sys.argv) > 1:
        option = sys.argv[1]
    else:
        option = ''
    if option == 'export':
        expAllGraphs()
    elif option == 'folder':
        userFilesFolder = PyOrigin.GetPath(PyOrigin.PATHTYPE_USER)
        os.startfile(userFilesFolder)
```

Figure 2.15 Python Language

(OriginLab Corporation, n.d.)

2.1.7 Web Camera

A webcam is a small camera attached to a computer. It captures still images or broadcast a video images real time. It captures light through a small lens by a tiny lattice of microscopic light detectors like a digital camera. Unlike a digital camera, a web camera has no built-in memory card, or flash memory chip. Webcams have USB cables at the back that gives power to the webcam. USB cable takes the digital data captured by the webcam back to the computer and then transmits the data to the Internet. (Woodford, 2017)

Figure 2.16 Web Camera

(Computer Hope, 2017)

2.1.8 Linear Actuator

A linear actuator is a device that moves between two points in a linear motion. Usually with two main components: a motor and screw. Linear Actuators transform the rotary motion of the electric motor to linear motion. (Power Jacks Limited, n.d.) Some linear actuator are made with conveyor belt and rollers.

Figure 2.17 Linear Actuator with Conveyor Belt

(Open Builds Part Store, n.d.)

2.1.9 Android

Android operating system is established based on the Linux kernel. It is developed by Google mainly aimed for tablets and smartphones. Created as an open source, many developers look forward to the operating system. The Android became the fastest growing mobile operating system. It can be easily modified and be added with enhanced feature to achieve the latest requirements of the mobile technology. Android operating system has key features such as Application Frame work, Optimized Graphics, SQLite, GSM Technology, Wi-Fi, Bluetooth, Camera 3G, and GPS. (Singh, 2014)

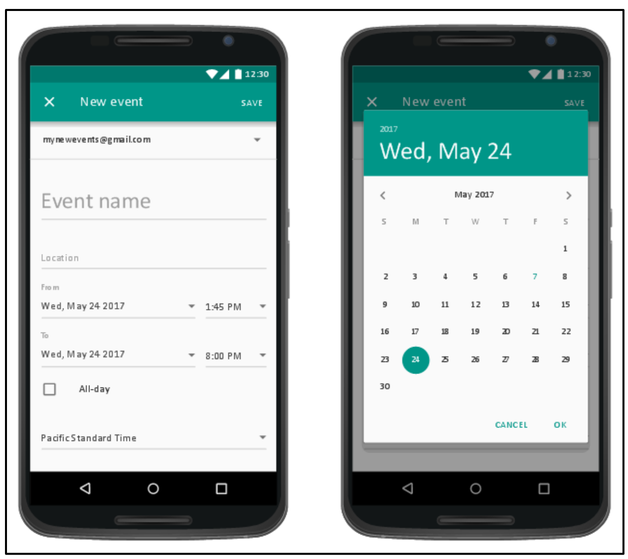


Figure 2.18 Android User Interface

(Full-Screen Dialog, n.d.)

2.1.9.1 Software Development Kit

Android provides Android Software development kit (SDK). This helps the software creators for better development of software and Java programming Language is provided. The Android SDK includes libraries, sample code, debugger, documentation, and tutorials. (Singh, 2014)

2.1.9.2 Android Application

Like other mobile applications, Android applications are developed in a host target development environment. Android apps are developed on a host that contains many resources and are downloaded to a mobile phone for trial or eventual use. A real Android device is used to test the applications. Most developers debug an application by using an emulator, and latter is easier for initial development and testing, followed by final testing on real devices. (Rogers, Lombardo, Mednieks, & Meike, 2009)

2.1.9.3 App Inventor

App Inventor is a visual, drag-and-drop tool used for developing mobile application on the Android platform. It involves the developer to design the user interface of an application through a web based graphical user interface builder. By placing the blocks like completing a puzzle, the application’s actions and task can be specified and sequenced. (Wolber, Abelson, Spertus, & Looney, 2011)

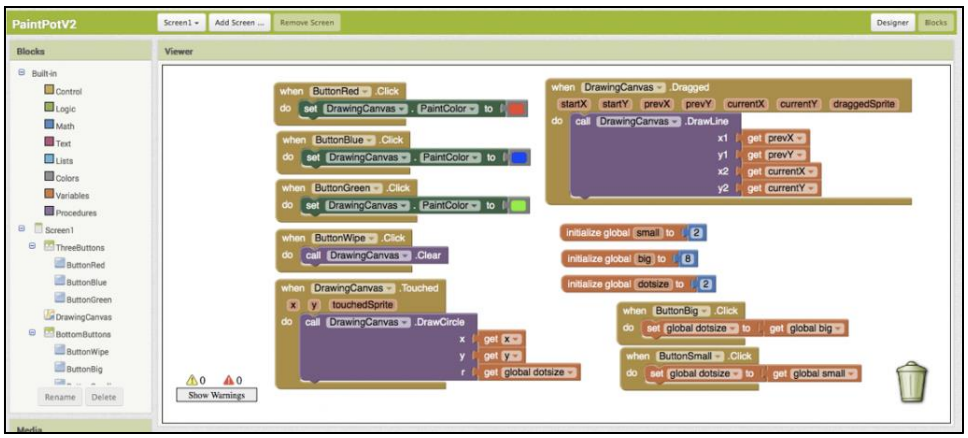


Figure 2.19 App Inventor Blocks Editor

(Learn Computational Thinking with MIT App Inventor, 2016)

2.1.10 Solar Photovoltaic System

2.1.10.1 Solar Photovoltaic Panel

A solar photovoltaic system converts sunlight into electricity. More electricity is yielded by a solar panel when there is more sunlight. Most PV system is normally used for power production in rural areas. These panels are created with a number of individual cells. Shape of the cells may be round, square or other type. A cell produces around a ½ volt that is why cells should be connected in series tin order to acquire a high voltage enough to charge a 12 V battery. (Wade, 2003)

Figure 2.20 Solar Panel

(Sendy, 2016)

2.1.10.2 Solar Charge Controller

Solar Panels can charge too much electricity into the battery without a charge controller which causes the battery to be overcharged. When a battery is overcharged, it becomes hot, and damaged. The charge controller is connected between the solar panels and the battery. It constantly checks the voltage of the battery by showing the battery that is full. The charge controller automatically stops electricity to be charged into a full battery. (Wade, 2003)

Figure 2.21 Solar Charge Controllers

(Rushworth, 2014)

2.1.11 Buck Converter

Buck converter meant a step-down converter, but is mostly termed as DC/DC converters. Extending the battery life, reduces heat are some of the advantages of efficient power conversion. It is used on USB on-the-go, battery chargers, solar chargers, and motor controllers. (Knight, 2015)

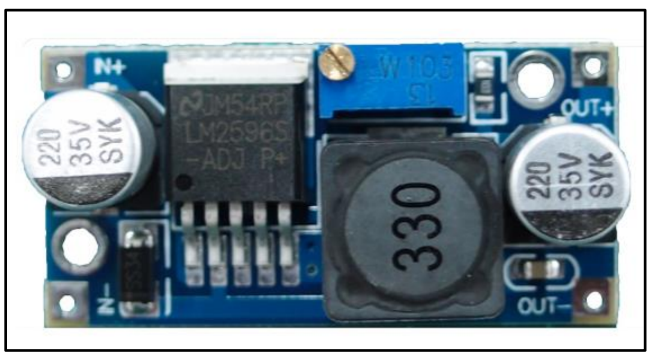


Figure 2.22 DC-DC Buck Converter LM2596S

(Maker Lab Electronics, 2015)

2.1.12 Inverter

An inverter is an electrical device that converts DC voltage from batteries, into AC voltage for utilization of common appliances. In short, an inverter converts direct current into alternating current. Since solar cells only produce DC, direct current is used electrical equipment like solar power systems. The power produced by DC generating devices needs to be available to regular AC appliances, that is why inverters are needed. (What is an Inverter?, 2013)

2.1.13 Relay and Relay Driver Circuit

Relays are components which permits a low-power circuit to switch a relatively high current circuit to be on or off. It control signals that is electrically separated from the controlling circuit itself. Often relay driver can be very simple. It can be done by using an NPN or PNP transistor to control the coil current. (Electus Distribution, 2001)

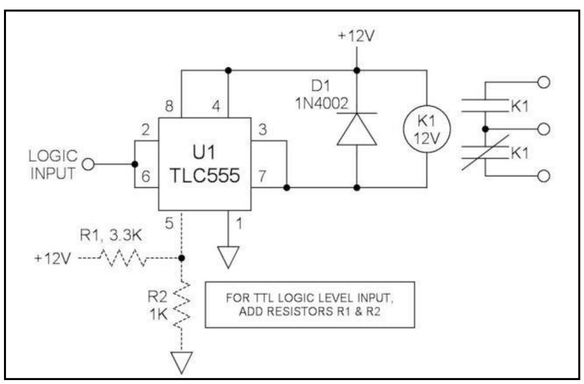


Figure 2.23 TLC555 Relay Driver Circuit

(Keith, 2012)

Figure 2.24 Electromechanical Relay

(Electronic Component, n.d.)

2.1.14 IoT Remote Access

The Internet of Things (IoT) refers physical objects connect to the Internet and to each other via sensors and wired or wireless technologies. It creates an ecosystem of universal computing. It is how computers, objects, and sensors connect and interact with each other to process data. (Federal Trade Commision, 2015) Remote access is the capability to gain access to internal network resources that are physically distributed. Remote access software provides authorized users at a remote site access to talk over a phone or ISDN line, to view electronic mail, run applications, and transfer files to and from the corporate computers. (Naaman & Peltier, 1998)

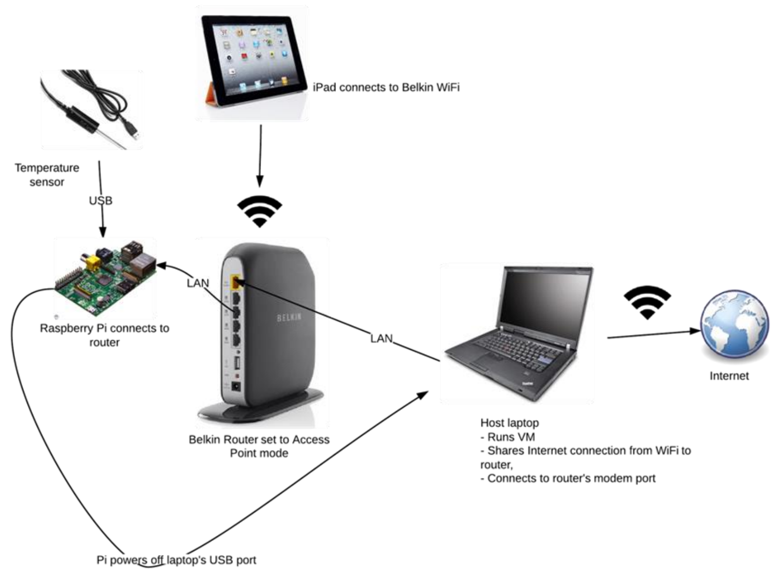


Figure 2.25 IoT Remote Access Setup

(IoT end-to-end demo - Remote Monitoring and Service, 2014)

2.2 Related Studies

2.2.1 Foreign Studies

A study entitled *Non-Contact Plant Growth Measurement Method and System Based on Ubiquitous Sensor Network Technologies* by Suk et al. (2011), based on this study, automation of plant growth measurement process can solve the problems created by existing measurement tools such as Vernier calipers, tapelines, contact sensors, etc. that causes damage to plants while measuring growth parameters. The proponents conducted system performance with the measurement data in field experiments. The proponents used IR sensors (infrared radiation) sensors to the surface of the plants stem and convert the amount of it into a quantity of electricity. Wi-Fi is used for the connection between the sensor nodes and the sink nodes which made up the ubiquitous sensor network. The data received by the sink node are transferred and stored at the control center through Internet. The data are then analyzed to determine the growth characteristics of plants.

In the study entitled *Design of a Smart Monitoring and Control System for Aquaponics Based on OpenWrt* by Wang, Zhao, Huang & Xu (2015), the proposed system can monitor the aquaponics using sensors in a real-time and automatically transmit the data of water level, light intensity, water temperature, humidity and photos to WRTnod. The latter is responsible for storing and analyzing the data gathered from the sensor nodes and camera. The users can also use the mobile terminal to monitor and control the smart aquaponics remotely.

As indicated in a study entitled, *Development of a Multi-parameter Plant Growth Monitoring and Control System for Quality Agriculture Application* by Wei-Chieh Tai et al. (2017), crop yield is unbalanced due to the drastic effects of climate change in current years. Instead of traditional agricultural system, smart farming uses agriculture automation system of traditional agriculture. It can collect the environmental data via smart phone. The crop yield are greatly linked with environmental parameters such as air temperature, air humidity, soil moisture, illumination. Its economic efficiency can be aimed by directing optimal cultivating setting. The study used MG82FG5B32 Developer Edition in MEGAWIN Technologies as a microcontroller. A database was created with MySQL for human-machine interface through website. The research developed a wireless monitoring and control system, wherein the system combines various sensors and manages long-term monitoring environmental parameters. Based on the sensors' data, such as regulating temperature, luminosity and soil moisture, the microcontroller can automatically state whether the system trigger the irrigation systems and fan. The study can also transmit data to access MySQL Database by Wi-Fi system.

As studied by Rustia and Chung (2016) on a research entitled, *A Multi-Functional Remotely Accessible Monitoring and Control System for Optimized Plant Growth*, a multi-functional monitoring and control system provided data collection and interpretation with feedback through local Wi-Fi connection or remote internet access via any portable device. The system is developed for faster plant production and higher crop yield. The crop used for the testing are lettuces which was grown on a closed environment with irrigation and lighting controlled. The system used two pots with lettuce, one using timed irrigation while the other using three different sensors to monitor the crop condition specifically soil moisture sensor, humidity and temperature sensor, and light intensity sensor. A light intensity sensor and a humidity and a temperature sensor was placed. A webcam was placed in front approximately 16cm away for monitoring and image acquisition. Image processing and monitoring system are reflected in a Web interface and database system. After a testing period of 30 days, timed irrigation yielded a relative growth rate of 0.2 while sensor-based irrigation produced 0.41 growth rate using image processing. The researchers suggested that the system must be applied on a farm as future application.

Based on the study of Yu-Hui et.al, entitled, *An Automatic Vision-Based Growth Measurement for Leafy Vegetables*, plant growth measurement designed was a stereo vision system that is composed of two cameras with parallel optical axes. It was combined with an image processing algorithm to monitor plants' growth of Boston lettuce in a plant factory. The cameras used in stereo vision system was connected on a sliding rail to extend the view of the camera to the planting beds or grow beds. The cameras move across the planting shelves to precise locations and then take images. To determine plant features and construct panoramic images, captured images of plants were constantly measured. The features of plants such as projected leaf area, height, volume and equivalent diameters were developed. A belt driven by a linear actuator was placed on the top of the planting beds with a brushless DC Electric motor and a brushless servo driver. According to Tsung-Cheng Lai, Open CV library functions were used in the image processing. The GrabCut algorithm from the OpenCV library was utilized to cut the plant area from the background and find the center of the image.

Chung, Rustia and Hsiang (2016) stated in their study entitled, *A Web-Based Greenhouse Automatic Control and Monitoring System,* that greenhouse monitoring become one of the modern trends in agriculture for the past years. The small greenhouse contains two baskets of tomato seedlings planted and was monitored through WiFi. The system is composed of ATMEGA328 MCU for sensor and controlling, Raspberry Pi for PHP server management, and ESP8266 module for HTTP server and PHP data sending. Hardware and sensors used in the study are light and irrigation relay, soil moisture sensor, and back-up timer module wherein the study compared the plant growth of two pots between automatic control and manual control. Image acquisition was made every 30 minutes within 30 days and the plants were compared through visual observation. The researchers determined that the automatic irrigation permits faster plant growth than the manual one. It is recommended data gathering and image acquisition should be further developed.

In a study of Bitella et al. (2014) entitled, *A Novel Low-Cost Open-Hardware Platform for Monitoring Soil Water Content and Multiple Soil-Air-Vegetation Parameters,* system for monitoring soil water content for agriculture was based on an open-source ARDUINO microcontroller-board and was programmed in simple integrated development environment. The research developed a low cost open hardware platform of different sensors for measurement of water content at multiple depths, soil and air temperatures. High-frequency dielectric sensors mounted on board resulted to temperature drifts. Integration of soil temperature measurements must be done with the mounted sensors. The probes resulted to sensitivity to small changes in water content with a single calibration in sandy, sandy-loam and loamy-clay soils.

Based on a study, *Smart Aquaponics System for Industrial Internet of Things (IIoT),* of Odema et al. (2017), the aquaponics system was based on Modbus TCP communication protocol which is widely utilized and standardized on industrial applications. The system evaluated the water quality through various sensors and actuators such as pH Sensor, temperature and humidity sensor, water temperature sensor, conductivity sensor, and dissolved oxygen sensor with relay for lighting, aerator and cooler. Readings from the sensors were taken every 5 min. The parameters are controlled manually through a switching button in an interface. This interface is only accessible through an ordinary browser within the local network as the web server.

A study, *An Automated Solar-Powered Aquaponics System towards Agricultural Sustainability in the Sultanate of Oman,* of Nagayo et al. (2017) discussed an aquaponics system designed to be cost-effective and environment friendly for communities of Oman. Water recirculation system, aquaponics control and monitoring system using Arduino, GSM shield and NI LabVIEW, solar energy conversion system, and cooling and heating systems composed the study for plant and fish growth. The Arduino microcontroller reads and processes the data from sensors that detect the water parameters. Water pumps, aeration pumps, exhaust fans, evaporative cooler, artificial lights and servo motor for fish feeder are triggered when readings are not within the normal limits. Data are displayed in LCDs in a GUI using NI LabVIEW software. The growth of water spinach and lettuce, and tilapia are monitored. The results obtained that the system's performance was sustainable to be utilized in Oman and other dry regions.

As studied by Murad et al. (2017) in a research entitled, *Design of Aquaponics Water Monitoring System Using Arduino Microcontroller*, Arduino software is utilized to develop a program that controls temperature sensor, pH sensor, water sensor, servo, peristaltic pump, solar, liquid crystal displays (LCD), and GSM module water monitoring of aquaponics. Rechargeable battery is used for solar energy. Peristaltic pump is switched on automatically when the pH is out of range. Water sensor is fixed to detect the water flow of the grow bed to fish tank. The temperature sensor is utilized for monitoring the temperature of the water.

In a study entitled Minimization of Temperature Ranges between the *Top and Bottom of an Air Flow Controlling Device through Hybrid Control in a Plant Factory* by Seung-Mi Moon, Sook-Youn Kwon, and Jae-Hyun Lim (2014), it is essential to install air flow devices such as air flow fan and cooling/heating device to facilitate air circulation in a plant facility. This study compares the temperature and air distribution within a closed-type plant factory using controlling cooling/heating devices and air flow fans. The cooling and heating devices were mounted at around 45° on the wall, and the temperature in the facility was set to 23°C as the growing condition of leaf vegetables were considered. The experiment results shows that the difference in temperature decreased by as much as 78.9% in the hybrid control of cooling and heating devices and air flow fans compared to that when only cooling and heating devices were functioned where the air scattering was enhanced by as much as 63.4%.

According to Hsien Ming Easlon and Arnold J. Bloom (2014) of the study entitled, *Easy Leaf Area: Automated Digital Image Analysis for Rapid and Accurate Measurement of Leaf Area*, Easy Leaf Area gives user-friendly technique for fast leaf area measurement and non-destructive canopy area estimation of digital images. The study focused on proving Easy Leaf Area software accuracy by batch processing hundreds of *Arabidopsis* rosette pictures in minutes, eliminating background noises and saving data results into a CSV file. The images were taken using a camera phone. To test the accuracy of the Easy Leaf Area, this software was initially compared with a LI-COR LI-3000 area meter, and ImageJ software a widely-used leaf area estimation software. All results were compared by a traditional, “paper doll” method of measuring leaf area. The study proved that the results taken from Easy Leaf Area were more accurate in fast processing than the estimates taken from ImageJ.

2.2.2 Local Studies

In a study entitled, *Development of Solar-Powered Arduino-based Smart Aquaponics System through Android IoT Application* by Lapuz et.al (2017), the proponents constructed three vertical aquaponics setups: Ion Sensitive Field Effect Transistor (ISFET)-monitored, glass-electrode monitored and unmonitored system, to compare the effects of the pH sensors to the plants and fishes in that system. The researchers proved the superiority and efficiency of the ISFET-based pH sensor over the commonly used glass electrode pH sensor through various experiment and testing its performance for evaluation. Interpreting the results of the testing and evaluation procedure opted to both pH sensors using t-test, the ISFET readings revealed no significant differences as compared to standard pH solutions unlike the glass electrode. In statistically accessing the results, the mean values of the ISFET readings were closer to the standard pH values indicating the ISFET pH sensor's accuracy. A reliable proof to this is the more promising length and weight of the plants and fishes produced by the ISFET-monitored setup compared to the two other setups. The researchers also developed an android application to display water parameter readings as well as the corrections performed by the system, providing convenient access for the users regardless of time and place.

As studied by Alcabasa et.al (2017) in a research entitled, *IoT-based Microfarm Prototype with Light, Soil Moisture and Temprature Sensors using Arduino as Sensor Node and Raspberry Pi as Gateway and Controlled using a Smartphone Application*, presents a research study conducted to allow the urban farmers to monitor their fam remotely through the development and innovation of an IoT-based microfarm prototype. The system created involves the detection of light intensity, soil moisture and temperature through the use of various sensors that were connected to the Arduino microcontroller. The abnormalities in the said parameters are corrected through the use of parameter regulators such as LED grow light strips, water pump and air cooler. The data gathered by these sensors through the use of the Arduino are stored to the web database via IoT gateway which was the Raspberry Pi computer chip. The data gathered by the sensors can also be reflected to an Android unit installed with the *Microfarm Companion* mobile application that capable of monitoring and even controlling the environmental parameters observed in a microfarm. It allows the user to view the real time current values of the parameters involved and to choose whether to control the parameter regulators automatically or manually. The microfarm system runs autonomously thus reduces the labor and time required to produce healthy crops. Mustard greens are used as samples in the testing of the system. It was observed that the average height of the samples were about 0.23 cm taller than the commercial mustard greens.

Based from the study entitled, *Development of an Android Application for Power Consumption Management System Using Programmable Toggle Switch by Iba*ñez (2015), the continuous increase in power rate in the Philippines signifies lack of supply to meet the consumer's demands. Increasing electricity consumption cost is added especially to the household budget. The researcher is then inspired to create a home automation technology to manage household power consumption by applying technology trends through the use of smart phones, internet and android application that is developed by using MIT App Inventor. The wireless data communication between the Smart phone and the Programmable Switch (PTS) is made possible through Arduino Wi-Fi shield and C language programmed in the Gizduino microcontroller. The PTS where the home appliance are connected interprets the command from the microcontroller and executes possible action based from the command performed in the android application. Thus, the control to the home appliance and the power consumption management at minimal cost in the household were at potential.

As stated by Amado et al., (2016) in the research entitled, *Horticulture of Lettuce (Lactuvasativa L.) Using Red and Blue Led with Pulse Lighting Treatment and Temperature Control in Snap Hydroponics Setup*, the capability of lettuce to grow significantly more and larger leaves increases when the environment of the lettuce was controlled. The study scoped on the evaluation of two experimental setups comparing the conventional SNAP hydroponics to the SNAP hydroponics using LED lights. The results manifest that LED as light source have a significant effect on the number of leaves ($t\ (41.7) = 6.07$, $p < 0.05$) and leaf area ($t\ (48) = 4.39$, $p = 0.05$) of a lettuce. The weight obtained using the hydroponics with LED lights setup (3.04 kg) was 30% greater than the weight attained with the conventional (2.18 kg) hydroponics setup.

According to Valenzuela et al. (2017) in a study entitled, *Quality Assessment of Lettuce using Artificial Neural Network*, the yield determination of crop health and seasonal development contributes in success of farming. Through the use of artificial neural network (ANN), a machine vision system was created for assessing the quality of a lettuce crop. This study can help farmers to evaluate the quality of the growing crops. Application of image processing for the feature extraction of the sample lettuce was also conducted in the study. Noise cancellation was performed to the image through thresholding. Separating the background and foreground was done before transforming the RGB components to into HSV color space. The image segmentation was done binarization: the background as black and the defect area as white. Feature extraction where a pattern was determined for ANN. Statistically, the trained network output data has no difference with the target data. The results show the correctness of ANN in the quality evaluation procedure of lettuce.

CHAPTER 3

METHODOLOGY

3.1 Research Design

3.1.1 Input-Process-Output Diagram

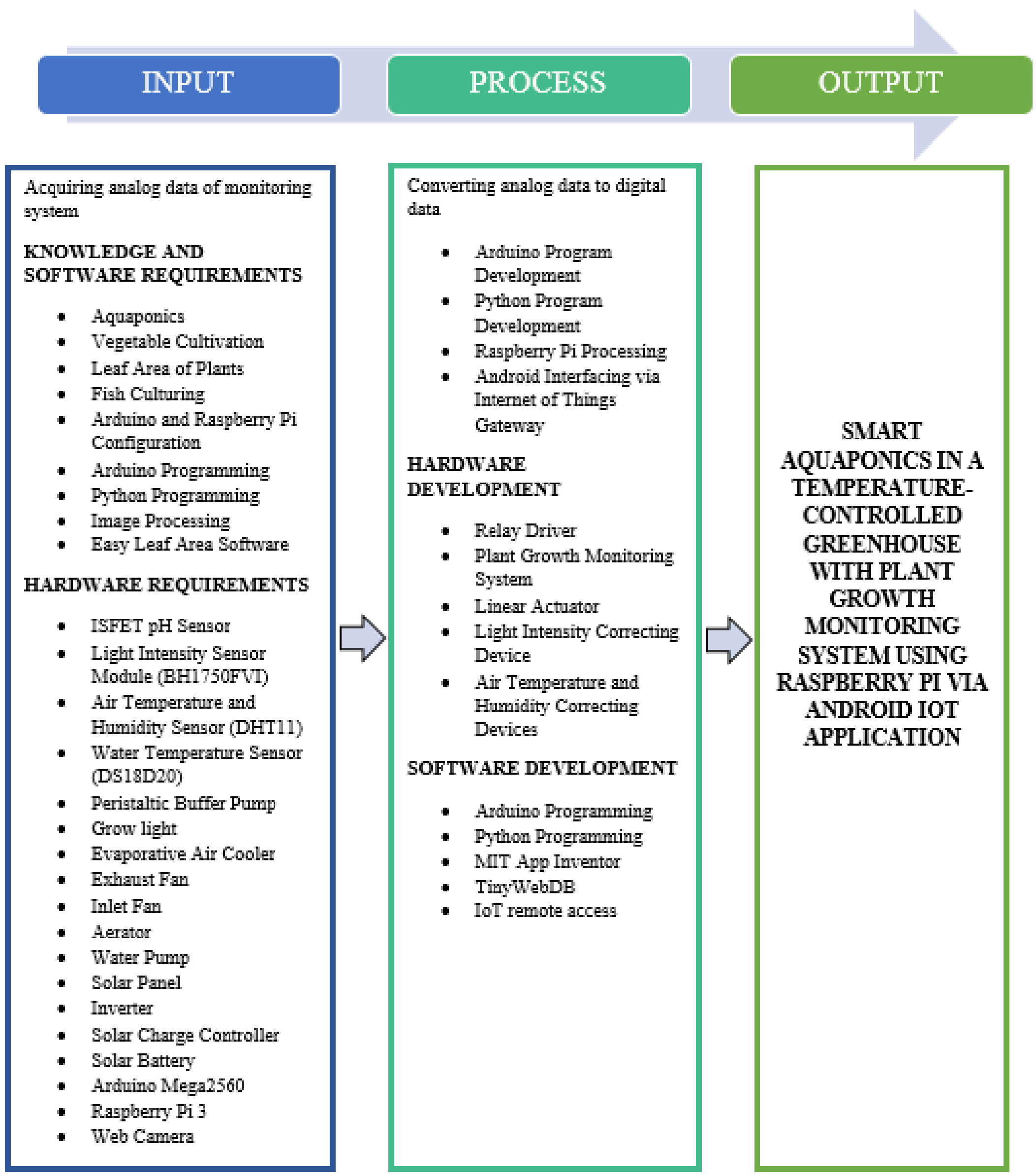


Figure 3.1 Input-Process-Output Diagram

To develop the aquaponics prototype and the Android application, knowledge, hardware, and software requirements were acquired as shown in Figure 3.1. The input block composed of requirements on knowledge, software and hardware. The software requirements were mainly for Arduino and Python programming on Arduino 1.6.7 IDE for Arduino Mega2560, and Python 2.7 IDE. MIT App Inventor IDE was required for the graphical user interface. The hardware requirements were composed of monitoring sensors such as the ISFET pH sensor, light intensity sensor, air temperature sensor, and water temperature sensor. The hardware was also composed the correction system devices such as the peristaltic buffer pump, grow lights, evaporative air cooler, exhaust and inlet fans, and aerator. Water pump was needed for the recirculation of water on the system. Arduino Mega2560 module was necessary for the connection of the monitoring sensors. The Arduino was connected to the Raspberry Pi Model 3 for data processing and transmission of data to the Android application. Analog readout circuit was responsible for the data gathering of the ISFET pH sensor before transmission to the Arduino. Relay driver circuit, buck converter, battery, inverter and solar panels were needed for the solar power technology. Plant growth monitoring system devices were also included such as linear actuator, and web camera.

The process block included analog data gathering of Arduino from the sensors and transferring of Arduino data to Raspberry Pi, analog data gathering of Python from camera, conversion from analog data to digital data, Arduino data analysis and processing, Python program image processing, and interfacing wireless connectivity via Internet of Things gateway. Assembly of the temperature-controlled greenhouse with the aquaponics set-up was included in the process block combined with assembly of light intensity correction device and plant growth monitoring system.

The output gathered from the sensors ISFET pH, light intensity, and air and water temperature readings were displayed on a graphical user interface of the Android application named, AquaDroid V2.0. The application was installed in an Android unit that shows graphs and real-time readings of the environmental parameter monitoring, automatic feeding, and plant growth monitoring system retrieved from the database.

3.1.3 Research Process Flow Chart

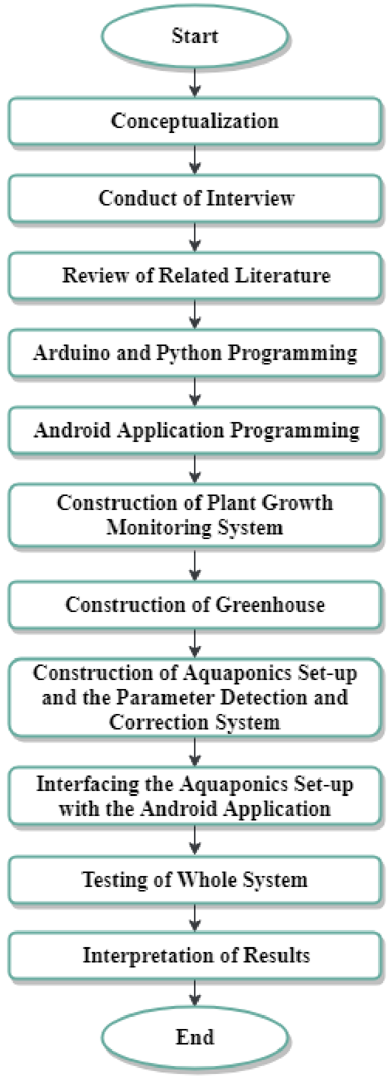


Figure 3.2 Research Process Flow Chart

Figure 3.2 shows the flow chart on how the research process chronologically occurred throughout the study. The process started from conceptualization on how the aquaponics came up as the topic, up to the interpretation of results after all the methodologies was done.

3.1.2 Block Diagram

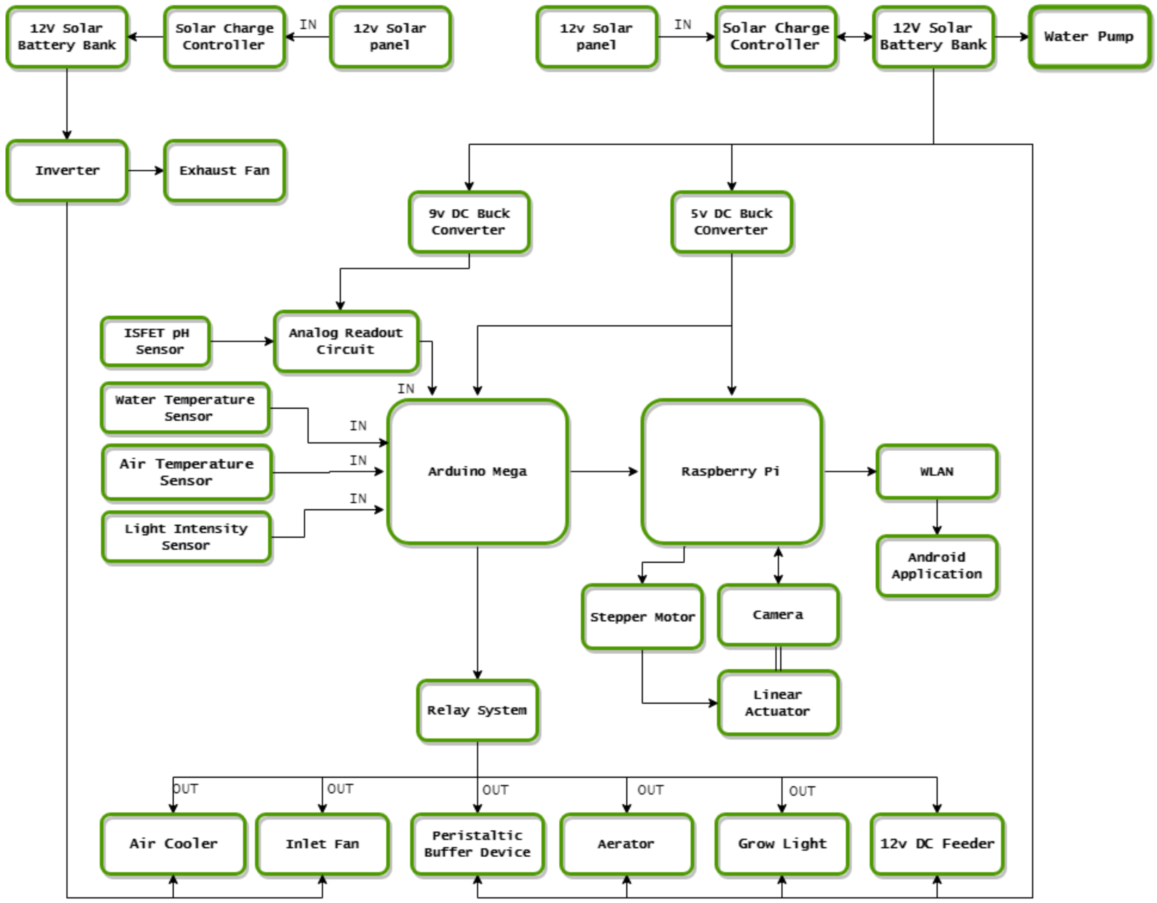


Figure 3.3 Block Diagram of the Smart Aquaponics System

The aquaponics system was composed of five sections namely the water parameter detection and correction, environment parameter detection and correction, automated feeding, plant growth monitoring system, and internet remote access.

3.1.2.1 Water Parameter Detection and Correction

The water parameters of the aquaponics system such as pH level and water temperature were monitored and controlled to achieve optimum growth of the plants in the grow bed and fishes in the tank. Each sensor connected to the Arduino Mega was set with threshold values to sustain best growth of Tilapia in fish tank, and pechay, lettuce and mustasa in grow beds. Correcting devices were automatically turned on when parameters were monitored at critical values.

The water's acidity and alkalinity were measured by the pH sensor. The pH sensor used was the Ion Sensitive Field-Effect Transistor or ISFET. The ISFET pH sensor readings were first sent to the analog readout circuit (ARC) for voltage amplification, and then sent to the Arduino Mega for data processing. Tilapia can tolerate a wide pH range which is pH 5.0 - 10.0 while plants prefer pH < 6.5. (Thorarinsdottir, 2015) Based on these conditions, the threshold range for the pH level for the system was from 6 to 8 ppm. If the pH < 6, the peristaltic buffer pump automatically released calcium carbonate (CaCO3) to add base and increase the pH slowly until the readings return at the normal pH range.

The temperature sensor used for the recirculating water was the DS18B20 temperature sensor that provided Celsius temperature measurements. The threshold value for the water temperature, T_{water}, was 25°C. If the T_{water} > 25°C, the aerator was automatically turned on to supply oxygen to the fish. Water temperature affect the capacity of water to hold dissolved oxygen. Cold water at high atmospheric pressure holds more dissolved oxygen than warm water at low atmospheric pressure (University of Wisconsin, 2006). If $T_{water} < 25°C$, the aerator was automatically stopped.

3.1.2.2 Environment Parameter Detection and Correction

The environment parameters inside the greenhouse namely light intensity, and air temperature were monitored and controlled to achieve favorable rate of plant production. Each sensor connected to the Arduino Mega were set with threshold values to sustain best growth pechay, lettuce and mustasa. Correcting devices were turned on when parameters were detected at critical values.

The sensor used to measure the air temperature for the greenhouse was DHT11 sensor. The temperature of air was measured by degrees Celsius. The suitable temperature range for most vegetables is 18–30 °C (Small-scale Aquaponic Food Production Integrated Fish and Plant Farming, 2014). The threshold value for the air temperature, T_{air}, was 25°C. If the $T_{air} > 25°C$, the evaporative air cooler was automatically turned on. If the $T_{air} < 25°C$, the inlet fan was automatically turned on which lets the cool air inside the greenhouse. If the T_{air} = 25°C, both the cooler and the inlet fan were automatically turned off. An exhaust fan placed on the wall of the greenhouse was always turned on to maintain the circulation of air inside the greenhouse.

A BH1750FVI light intensity sensor was utilized to measure the illumination for the plant grow beds. The threshold value used for the light intensity was 500 lx. If the light intensity was < 500 lx, the grow light was automatically turned on to act as an artificial light to supply the illumination needed by plants for growth processes and photosynthesis during night time.

3.1.2.3 Automated Feeding

The automatic feeder was created for the operation of food dispensing to the fish. It was programmed with an initialized default time setting in the Arduino Mega which turned on every 8 hours. It dispensed around 15 grams fish food within a period of 3 seconds. Every operation happened when the Arduino sent digital signal to the relay driver for feeder to dispense food.

3.1.2.4 Plant Growth Monitoring System

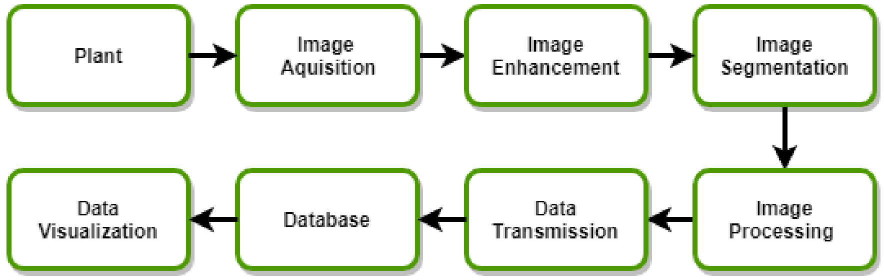


Figure 3.4 Block Diagram of Plant Growth Monitoring System

Figure 3.4 shows the process of plant growth monitoring of the aquaponics system. Plant growth monitoring system was composed of image processing wherein the images of plants were captured by the camera connected to a linear actuator that was responsible for camera movement from first plant to next plant. The captured images underwent image enhancement, image segmentation, and dimension acquirement using a Python program in a Raspberry Pi module. The projected area acquired from the image processing was transmitted to the database and to the Android application for data visualization.

3.1.2.5 Internet Remote Access

The internet remote access includes the transmission and reception of data report between the system and the Android application. The output obtained from the parameter detection and its analysis on Arduino Mega as well as the data acquired from the plant growth monitoring system were transmitted by the

Raspberry Pi and were stored to the database. The values were visualized in an Android unit through graphical user interface of the AquaDroid Version 2.0 Application.

3.1.4 Gathering of the Related Facts or Information

Aquaponics

A foundation of knowledge regarding Aquaponics was essential for the proponents to gain. These included the hydroponics and aquaculture fundamentals that were needed as the Aquaponics was the primary concept of this study.

Pechay, Lettuce, and Mustasa

Plant research regarding its biological requirements and its measures of growth including pH level, and air temperature was needed to be considered for proper growing of the plants on an aquaponics setup.

Tilapia

Behavioral study and growth requirements of tilapia was needed for appropriate cultivation of the species. The cultivation of the species relied on its adaptation to its environment and how its responds to the given ecosystem.

Plant Growth Monitoring

Vision-based plant growth measuring required the knowledge about cameras and image processing as the instrument for plant analysis. There was a need of researches about providing alternative and more efficient solutions to time-consuming traditional way of plant measuring.

Greenhouse Ventilation System

The proponents acquired concepts on how to maintain temperature on a greenhouse. Studies were considered in creating the size, dimension, design and system of the greenhouse as the control for the air temperature was essential for the plant and fish growth.

Air, Water and Light Parameters

Researching about the environmental parameters the system was also important. Air, water and light parameter monitoring knowledge, as well as the concept of correction was needed for the cultivation and growth of the plants and fishes.

Consultation with related agency

Consideration of the information directly from the agencies that were related to the study is vital in the development of the study. Agency specifically Bureau Agricultural Research, and people involved with maintaining aquaponics sites and has proficiency on aquaponics such as the Pasay City Hall Cooperative were directly consulted and given inquiries for the progress of the study.

Searching for location

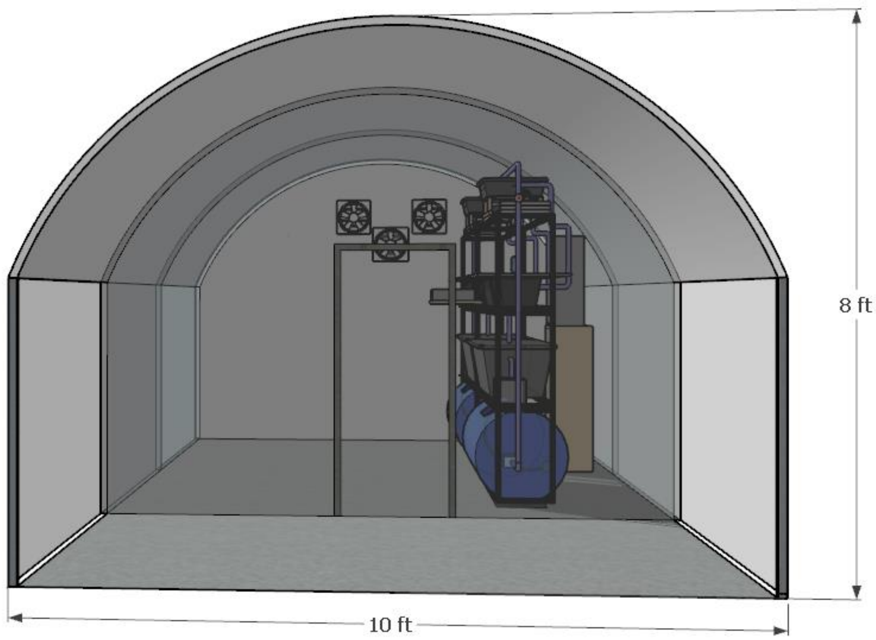
In fulfilling the system, location for the aquaponics set up was needed to consider the space and environment where the aquaponics setup and its greenhouse is installed. The proponents searched for an aquaponics site for conducting of testing, and evaluation to complete the study.

3.2 Project Development

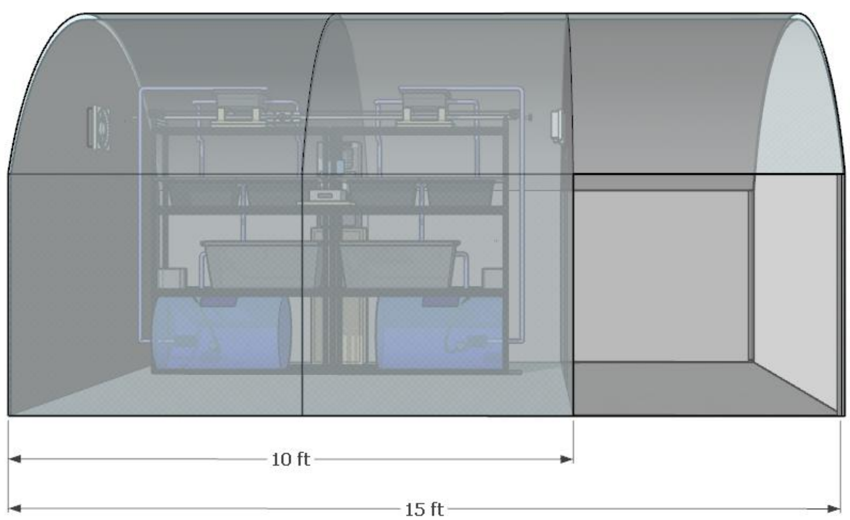
The development of this research project is divided into two phases: hardware development and software development.

3.2.1 Hardware Development

Hardware components used in the development of the system included a greenhouse and its cooling and ventilation system, and sensors such air temperature sensor, water temperature sensor, ISFET pH sensor, light intensity sensor. Hardware was composed of parameter correctors including air cooler, exhaust, inlet fans, aerator, peristaltic buffer pump, LED grow lights, and fish feeder, which were connected to a relay system. Included also in the Hardware were ArduinoMega microcontroller that functioned as sensor node, and Raspberry Pi that acted for the plant growth monitoring system and functioned as IoT gateway. The solar power technology was also included on the hardware development.



(a)



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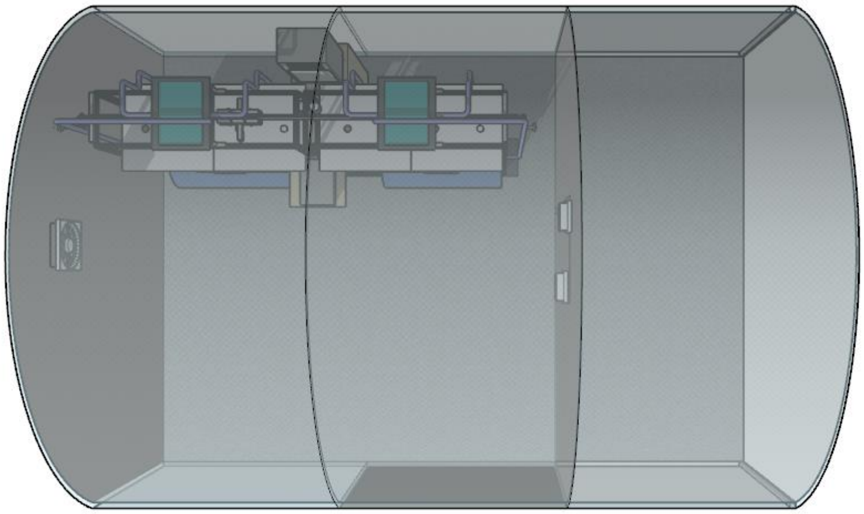

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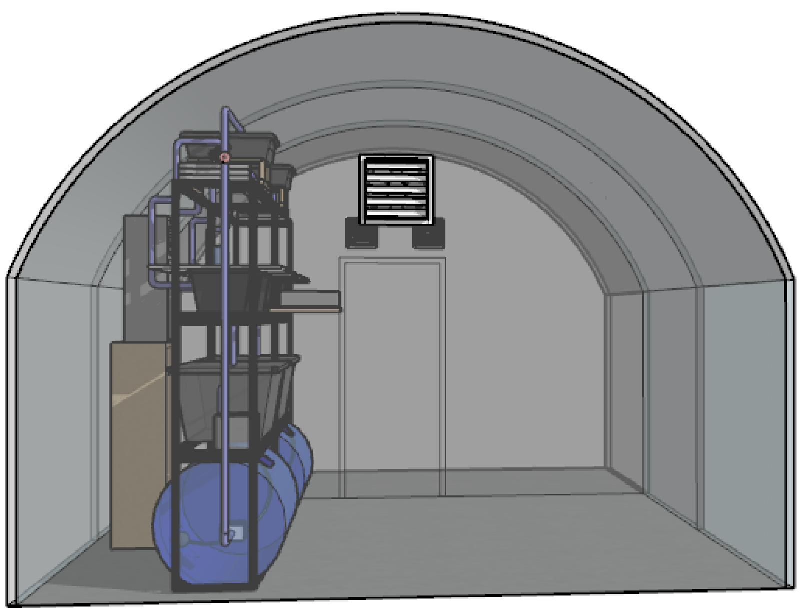


(d)

Figure 3.5 The Greenhouse Design and its Dimensions

(a) Front View, (b) Side View, (c) Top View, (d) Rear View

Figure 3.5 shows the dimensions of the greenhouse design. The greenhouse has width of 10 ft, length of 15 ft and height of 8 ft. It was constructed with aluminum framing and polyethylene sheets.

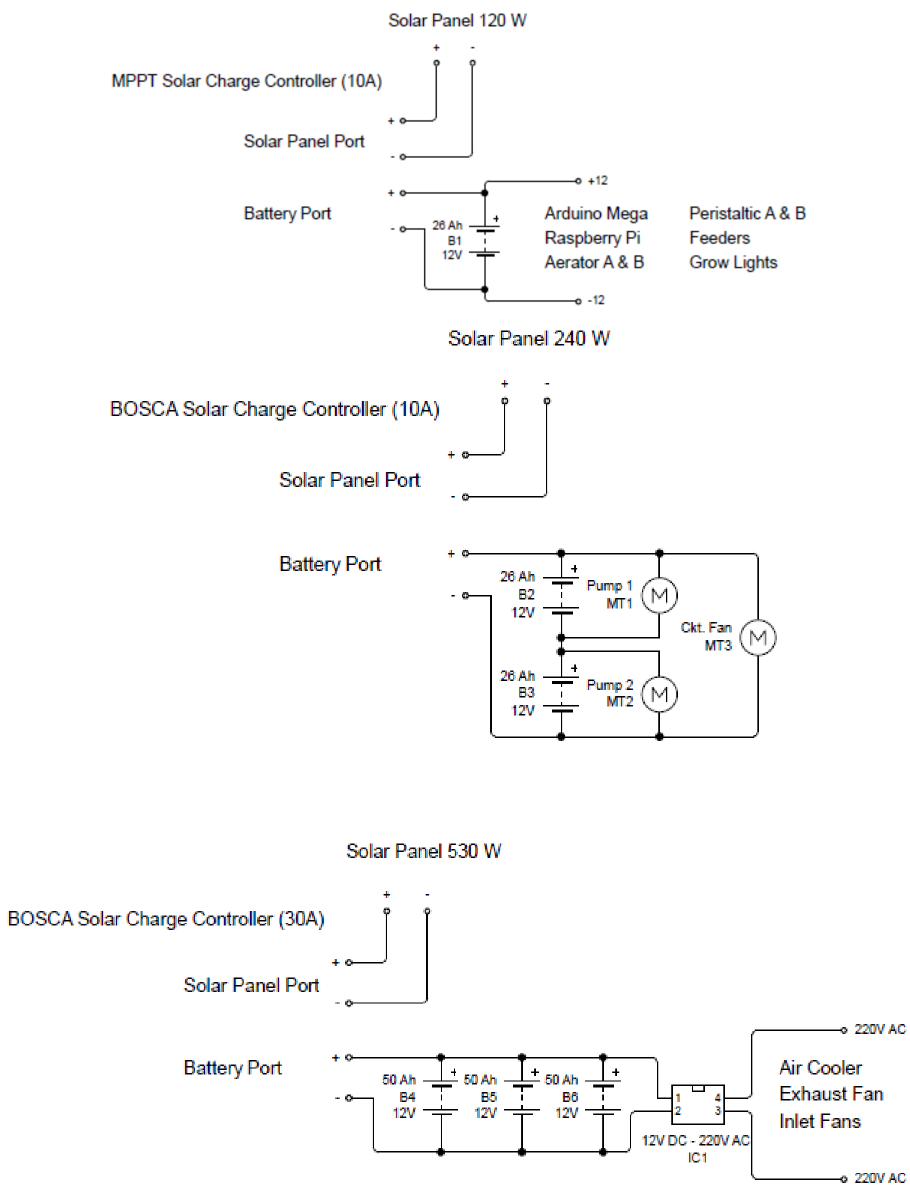


Figure 3.6 Solar Power System Circuit

Figure 3.6 shows the solar power technology circuitry. The whole system was powered by two 265 W solar panels and three 120 W solar panels connected to two solar charge controllers and six 12 V solar batteries. One 120 W solar panel was connected with an MPPT solar charge controller and charging a 12 V 26 Ah battery. This part was sustaining the loads such as the microcontroller module, aerators, peristaltic pump, feeders and grow lights. The 240 W solar panels (two 120 W) were connected to a BOSCA solar charge controller which supplies two 12V 26 Ah batteries. These batteries were attached to two water pumps and the circuit box fan. 530 W solar panels (two 265 W) were wired to another BOSCA solar charge controller which supplied three paralleled 12 V 50 Ah batteries. These batteries were connected with 12 VDC to 220 VAC inverter to supply the air coolers, exhaust fan and two inlet fans.

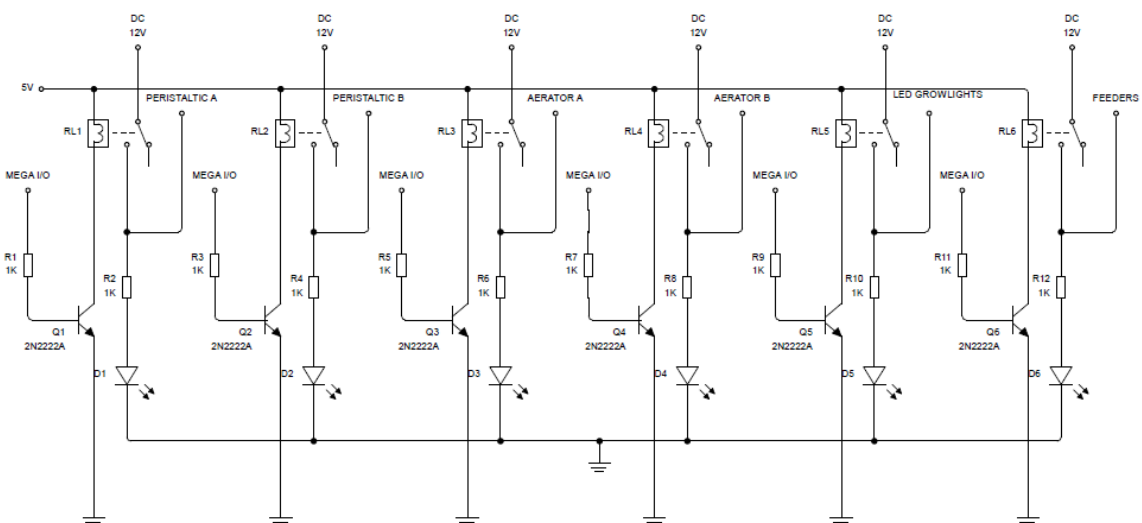
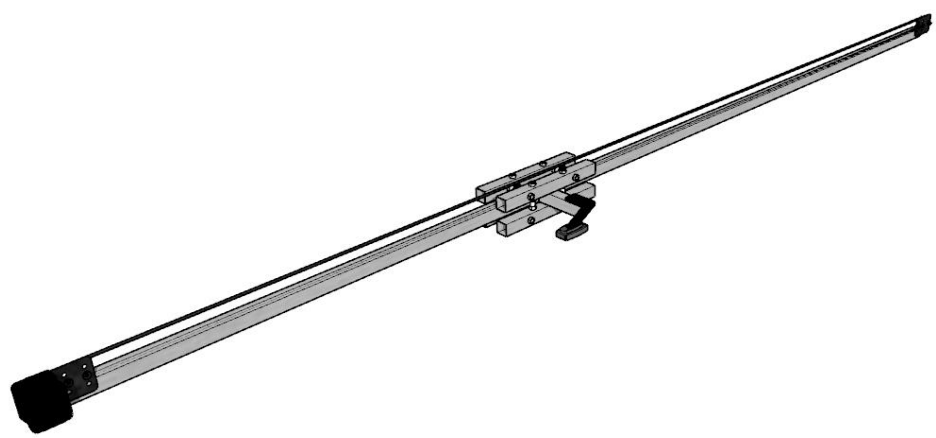
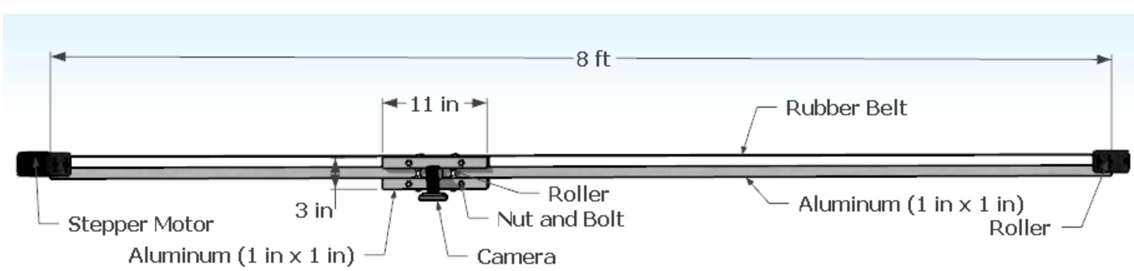


Figure 3.7 Relay System Circuit

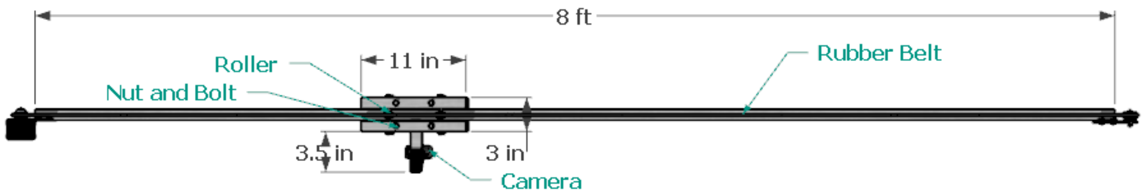
The relay driver circuit, as shown in Figure 3.7, controlled the water and environment parameter correction system and automatic feeding system. The two relay drivers for the pH corrector turned on the two separate automatic buffer devices for two aquaponics setup. Two relay drivers controlled the water temperature correcting devices composed of two aerators. One relay driver manipulated the two fish feeders for the two aquaponics setups. One relay driver controlled the grow light for correcting the light intensity, and another two relay drivers controlled the air cooler and the inlet fan which were responsible for the air cooling and ventilation system of the greenhouse.



(a)



(b)



(c)

Figure 3.8 Linear Actuator Design

(a) Isometric View, (b) Front View with Parts and Dimensions,

(c) Top View with Parts and Dimensions

Figure 3.8 shows the parts and dimensions of the linear actuator. The linear actuator was primarily composed of a 1 inch by 1 inch hollow aluminum bar with a length of 8 feet, Nema 17 stepper motor with specification of 1.8 degrees per step, and a rubber belt. The stepper motor was ran by a L293 IC driver. The web camera used in the growth monitoring system was connected to the linear actuator which manipulates the camera's movement from one plant to another. A 5-megapixel Logitech C310 HD webcam was used, and it was set 15 inches at the top of the grow beds. The Python program from the Raspberry Pi 3 module controls the moving and stopping of the stepper motor. Figure 3.9 shows the actual linear actuator applied in the project.

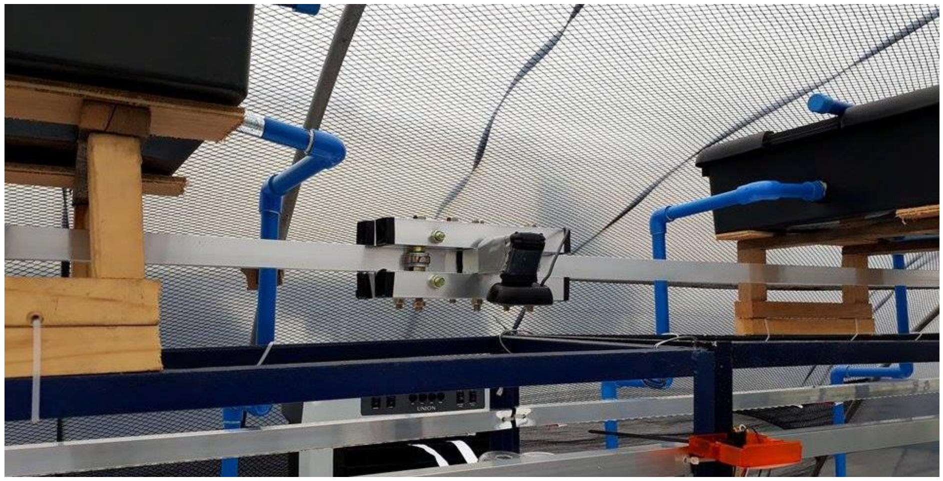


Figure 3.9 Actual Linear Actuator

Figure 3.10 shows the LED strip used in the project. LED grow lights were used as its correcting device. The grow lights has super bright 5050 SMD LEDs. SMD (Surface-Mount Device) LED module 5050 delivers 0.24W of power. The grow lights was 9 inches away from the grow beds.

Figure 3.10 Grow Lights

Air cooler, and two fans for the inlet were used as the correcting devices. Figure 3.11 shows the air cooler applied in the system. The air cooler used was the Union UGAC-003 Perfect Timing Air Cooler. This air cooler has a water tank capacity of 7 litres and has a dimension of 12.5×45×65cm. Two fans with diameter of 12 inches served as an inlet for the cool air to be drawn from the outside into the greenhouse as shown in Figure 3.12. One 14-inch diameter exhaust fan functions continuously for the system ventilation as shown in Figure 3.13.

Figure 3.11 Evaporative Air Cooler

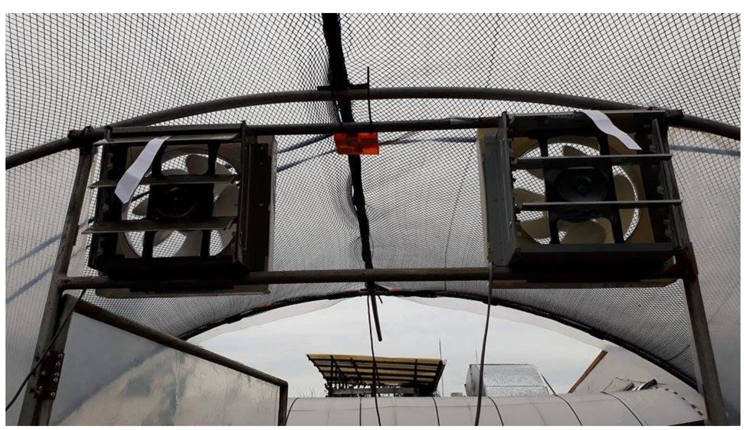


Figure 3.12 Inlet Fans

Figure 3.13 Exhaust Fan

3.2.2 Software Development

The gathered current signal, and controlling of the correction system were processed using the Arduino 1.6.7 IDE with algorithm-based decision support system.

The Python 2.7 IDE was used for the image processing of the acquired plant images from the camera, and for controlling the movement of the linear actuator during the capturing of the camera in every plant. IoT Gateway was programmed using the Python IDE wherein the signal from the Arduino was processed and sent to the Android Application using Wi-Fi. A program was developed for the image processing. The image enhancement contained the process of separating the foreground of the image from the background through image masking. RGB values were converted to L*a*b values then a threshold range of color green was set to be identified on the image. Through image morphing using erosion and dilation, the image was contoured and structured.

The boundaries of the foreground object were eroded, the size of the foreground object increased, and the gaps were closed. In image segmentation, a black and white image was formed through binarization. The white image acted as the plant area and the black color represented the background. The number of pixels were counted and underwent pixel to centimeter squared conversion. Figure 3.14 shows the program of image processing in the aquaponics system.

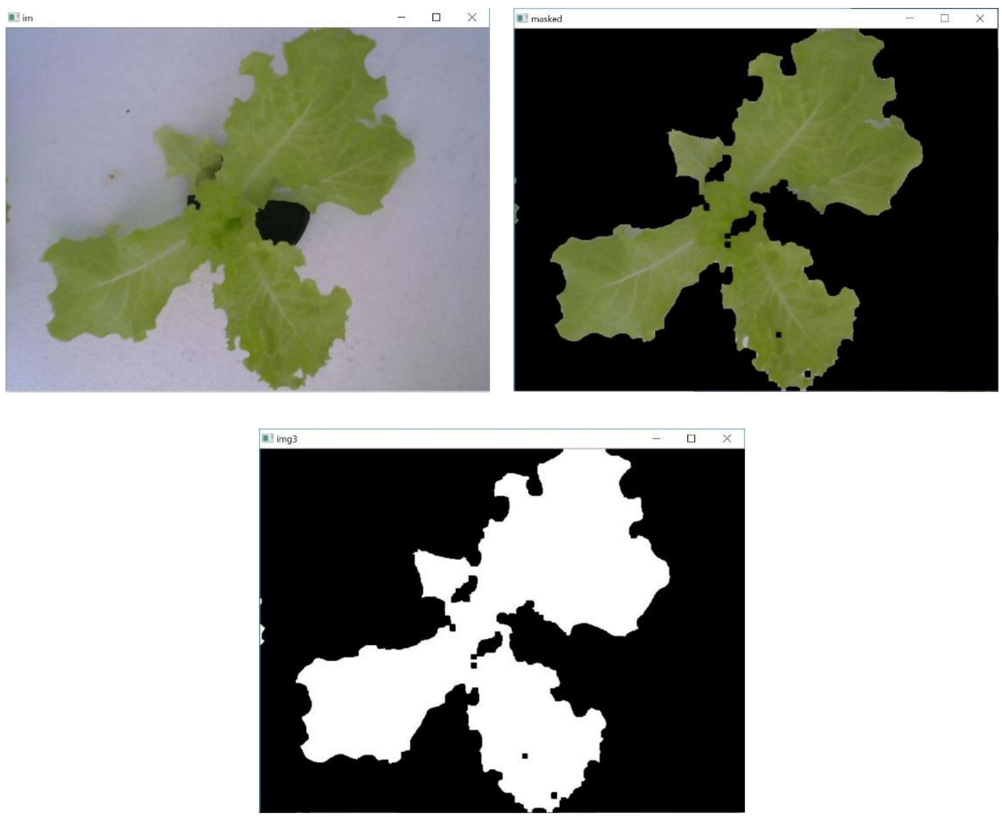


Figure 3.14 Image Processing of Plant Growth Monitoring System

The MIT App inventor IDE was used for developing the AquaDroid V2.0 Android application which served as the GUI of the system. The user can monitor the aquaponics system's pH, air and water temperature, light intensity, and the projected area of the plants form the plant growth monitoring system using the Android application.

TinyWebDB, a component App Inventor, was used to continuously store the acquired data from the sensors. Through a developed program using Python IDE, the TinyWebDB service was called to respond as a database by storing data and then called by the MIT App Inventor to transmit data to be shown by the Android application.

IoT remote access in the aquaponics system which involves transmitting and receiving data from the sensors to the wed database and to the Android application was developed and processed using Python programming.

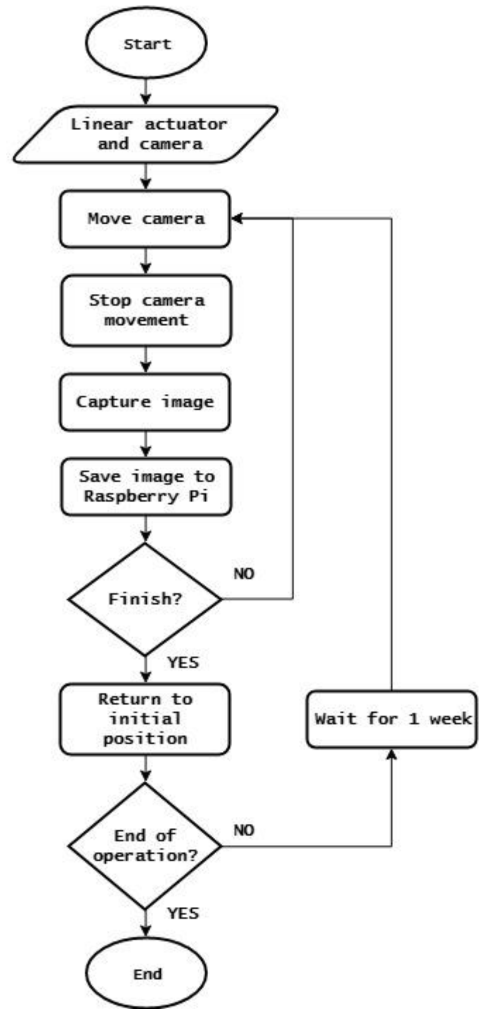


Figure 3.15 System Flowchart for Plant Image Capturing

Figure 3.15 shows the image capturing process of web camera mounted to the linear actuator. The image acquisition programmed using Python IDE was the initial process of plant growth monitoring before it undergo image processing. The camera movement atop one plant to another was controlled by the linear actuator. In the event when all of the plants were captured, the linear actuator moved the camera back to its initial position. Same process was programmed to happen every one week.

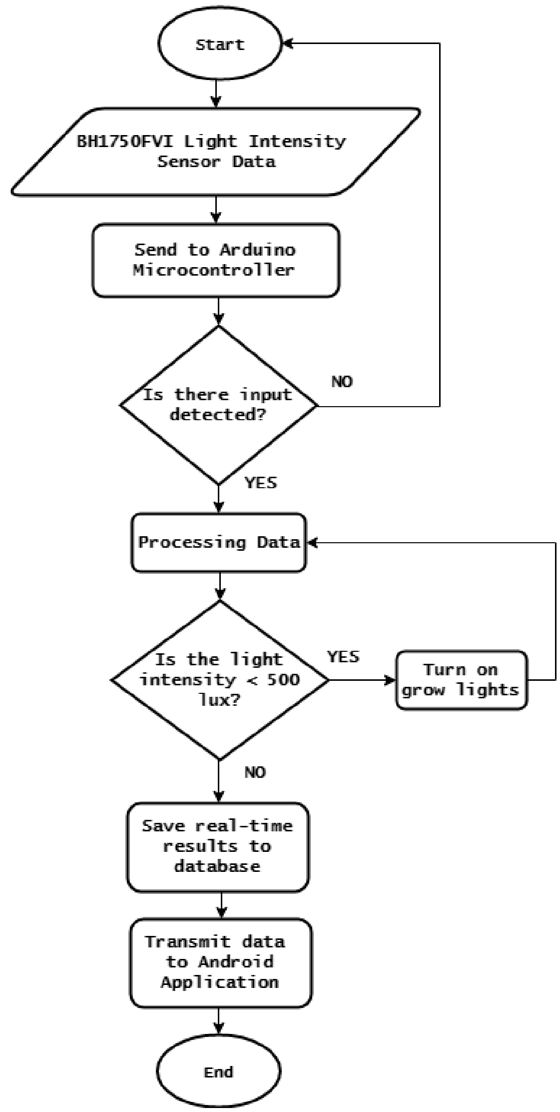


Figure 3.16 System Flowchart for Light Intensity Correction

Figure 3.16 shows the light intensity correction system. The threshold value for the light intensity was 500 lux. When the measured data was less than 500 lux, the grow lights were turned on. The grow light remained to be off when the data is above the threshold value indicating the normal level. All values were transmitted and shown on the android application.

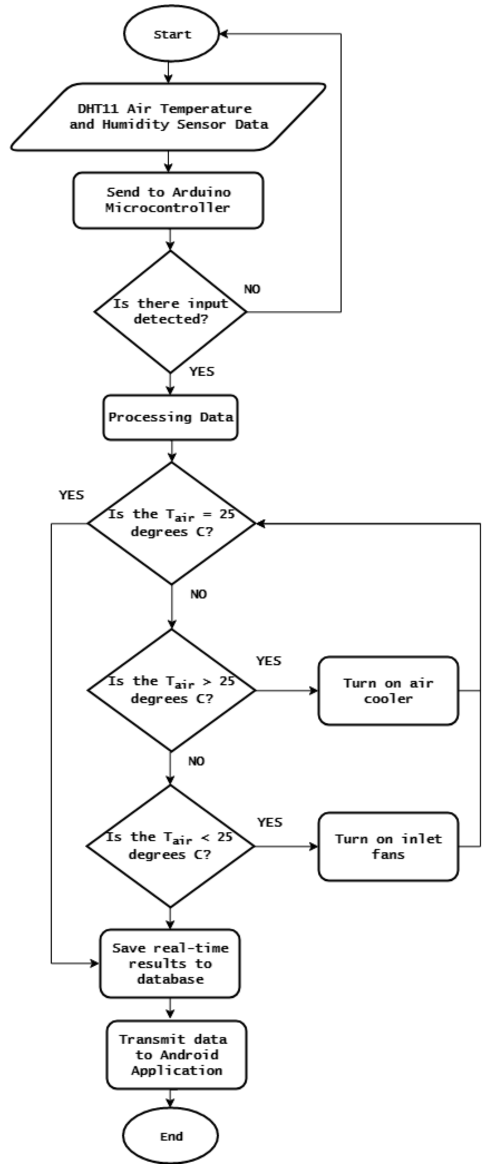


Figure 3.17 System Flowchart for Air Temperature Correction

Figure 3.17 shows the air temperature correction system. The threshold value for the air temperature was 25°C. When the measured data was greater than 25°C, the air cooler was turned on. When the measured data was less than 25°C, the inlet fans were turned on. The correcting devices were turned off when the value reached the normal level. All values were transmitted and shown on the android application.

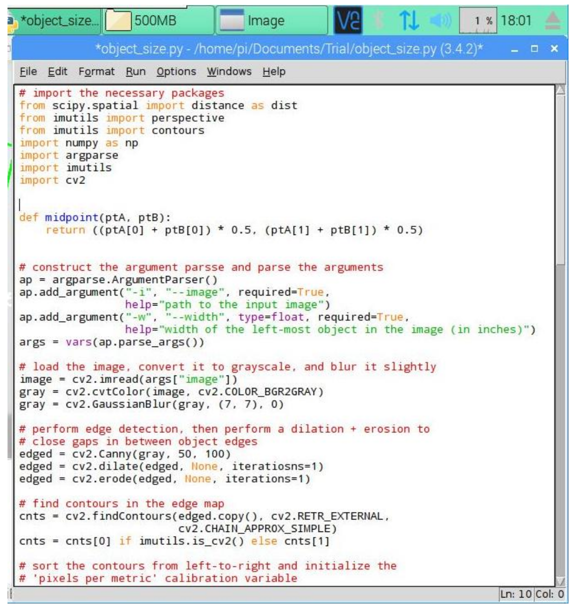


Figure 3.18 Python Program Screenshot

Figure 3.18 shows the Python IDE containing the source code of the plant growth monitoring system. The program also contain the codes responsible for the IoT access gateway of the aquaponics system.

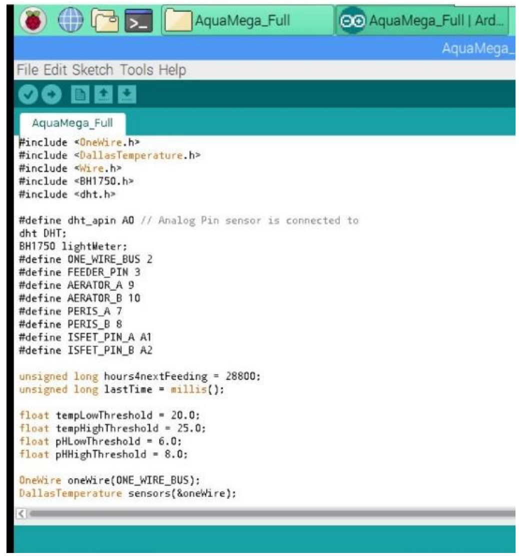


Figure 3.19 Arduino IDE Program Screenshot

Figure 3.19 shows the Arduino IDE comprising the source code of the water and environment parameter of the aquaponics system.

Figure 3.20 AquaDroid V2.0 Android Application Screenshots

Figure 3.20 shows the screenshots of the graphical user interface of the Android application. Values from the database were shown and visualized through Wireless Fidelity wherein both the Raspberry Pi and the phone were connected to the internet.

3.3 Materials and Equipment

Table 3.1 Materials and Equipment List

Qty	Specification	Description	Amount (Php)
2		ISFET pH Sensor Kit	12,450.00
2	12V	Magnetic Centrifugal Water Pump	1,620.00
2	12V	Aerator/Air Pump	1300.52
2	12V	DC motor	800.00
1		Arduino Mega 2560	900.00
10	12V	LED Grow lights Strips	983.00
1		Temperature and Humidity DHT11 Sensor	350.00
1		DS18B20 temperature sensor	130.00
1		BH1750FVI Light Intensity Sensor	315.00
3	12V	Exhaust Fan	3,000.00
1	220V AC	Evaporative Air Cooler	4,000.00
2		Belt Pulley	750.00
1	5m	Rubber Belt	750.00
1	3.6V	Stepper Motor	800.00
1	4m	Aluminum Rod	280.00
2	8MP	Web Camera	2,000.00
1		Raspberry Pi	2,400.00
2	6x4	Universal Printed Circuit Board	180.00
1		L293D	40.00
7	5V,6A	Relay	200.0
14	1K ohm,1/2 W	Resistors	28.00
7		Red LED	]21.00
7		LED Holder	21.00
50		Jumper Wires	250.00
3		High-Reliable Flexible Pins	90.00
4	34L	Deco Box	1,319.00
2	208L	Drum	1,200.00
1	400Ml	Calcium Carbonate	1,200.00
		PVC Pipes and Elbows	458.00
		Trellis	0
1		Polyethyelene Plastic	3,000.00
4	150W (3), 100W (1)	Solar Panel	25,000.00
2		Solar Charge Controller	600.00
TOTAL			66,405.00

3.4 Testing Procedure

The pH level of water of the aquaponics system was tested by immersing ISFET pH sensors to pH 7 and pH 4. The range of normal values set for the aquaponics setup is from 6.0-8.0. The pH 7 solution was used for the immersion of pH sensor for the first trial. The signal detected by the Arduino was sent to the Raspberry Pi and was expressed as a normal pH level. The second trial involves the immersion of the ISFET pH sensor to the pH 4 solution. The signal detected by the Arduino was sent to the Raspberry Pi and was considered acidic. As a correction to the irregularity of the result, the correction system triggered the peristaltic pump with Calcium Carbonate (CaCO3) to release the solution to the water.

The temperature of the water of the aquaponics system was detected by using DS18B20 sensor where the trial was conducted by submerging the sensor to the water. The threshold value programmed on the Arduino for the temperature of the water is 25°C. Conducting the first trial involved the submerging the sensor to the water and the water temperature was read by the Arduino and sent to the Raspberry Pi. The second trial involved with the use of hair blow dryer until the water temperature reaches 25°C, and then the correction system triggered the aerator to turn on for the water to go back to normal value.

The light intensity of the illumination of the plants was tested by using BH1750FVI light intensity sensor. The threshold value programmed on the Arduino for the temperature of the light intensity is 500 lux. In the first trial, the light intensity sensor was exposed to normal illumination and the output was read by the Arduino and was sent to Raspberry Pi. In the trial two, the light intensity sensor was covered with an opaque covering and the output read by the Arduino lowered until the light intensity lowered to 500 lux and the data was sent to Raspberry Pi. The correction system triggered the LED grow lights to turn on until the light intensity go back to normal value.

The air temperature inside the greenhouse was tested using the DHT11 sensor wherein the trials were conducted by subjecting the sensor to different test temperature. The threshold value programmed on the Arduino for the air temperature is 25°C. Conducting the initial trial involved the exposing the sensor near cubes of ice. The air temperature was read by the Arduino and sent to the Raspberry Pi. The correction system was triggered resulting the inlet fan to be turned on. Another trial involved exposing the sensor near a hair blow dryer until the air temperature reaches 25°C, and then the correction system was triggered resulting the air cooler to be turned on.

The plant growth monitoring system was also evaluated by assessing the accuracy of the Python image processing program. Under 20 image samples, the program was compared to Easy Leaf Area Software which is a tool that rapidly and accurately measures leaf area in digital images in seconds.

3.5 Evaluation Procedure

To evaluate the accuracy of the BH1750FVI sensor, the actual device readings were compared to digital light meter readings. Also, the DHT11 readings was compared to digital thermometer readings at the same testing time to evaluate the accuracy of the DHT11. The results of the evaluation procedures were assessed by the Pasay city cooperative officer, and an eco-modular specialist.

3.5 Gantt Chart

Activities	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Brainstorming for the project study	■															
Interview with concerned parties and agencies				■	■			■	■	■						
Topic Defense		■														
Research on facts about the topic	■	■	■	■												
Chapter 1: The Problem and its Setting			■	■												
Title Defense					■											
Chapter 2: Review of Related Literature			■	■	■											
Planning and design				■	■	■	■	■	■	■						
Chapter 3: Methodology						■	■	■	■	■	■					
Testing for sensors and Correction devices								■	■	■	■	■				
Progress Presentation									■							
Setting up and operation of the project										■	■	■	■	■		
Pre Final Defense												■				
Project monitoring, and evaluation													■	■	■	
Finishing the documents												■	■	■	■	
Final Defense																■

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Project Technical Description

4.1.1 The Greenhouse and the Aquaponics Set-up

Inside the greenhouse (10 ft x 8 ft x 15 ft) situated two aquaponics set-ups with height of 6 ft and length of 4 ft. One setup held two heads of pechay and two heads of lettuce, and the other set-up held two heads of lettuce and two heads of mustasa. Each set-up was consisted of 15L storage box as filter, two 34L storage box as grow beds, a 100L sump tank, and a 200L blue plastic drum as fish tank. The parts of each set-up were constructed with the same type of materials.

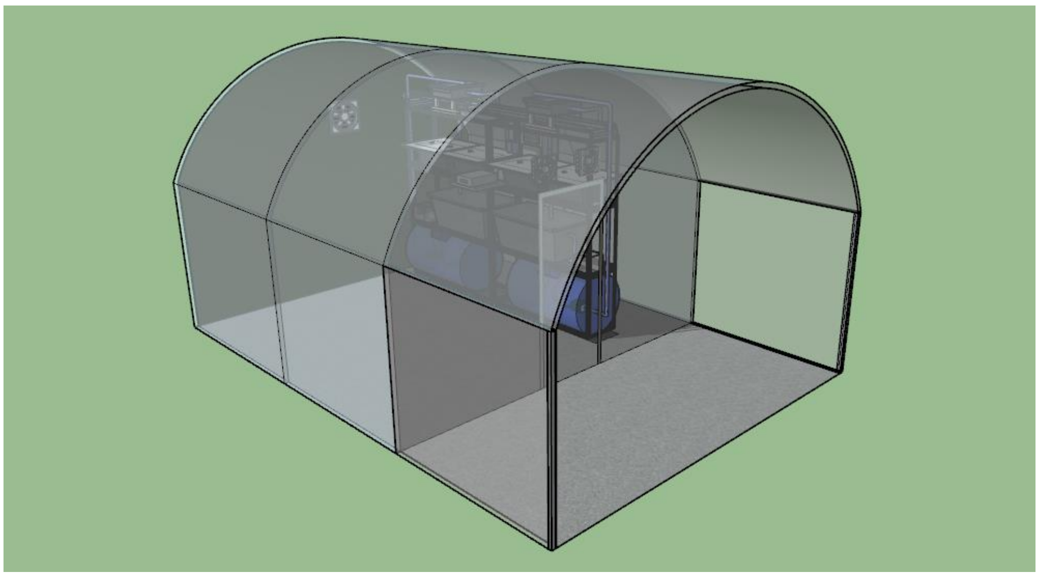
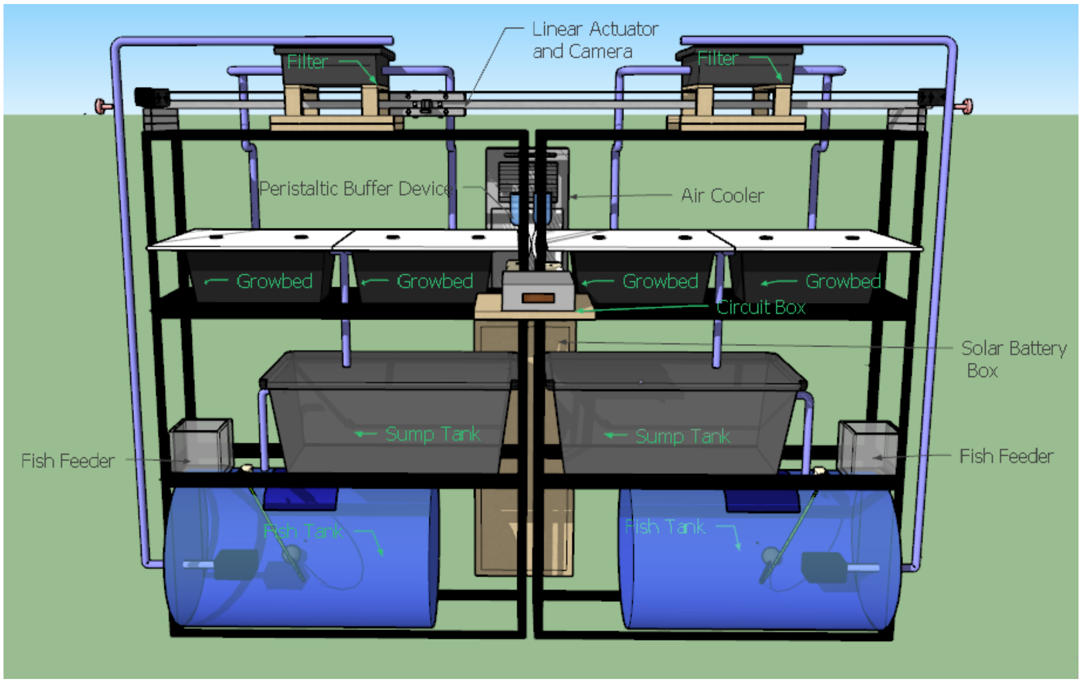
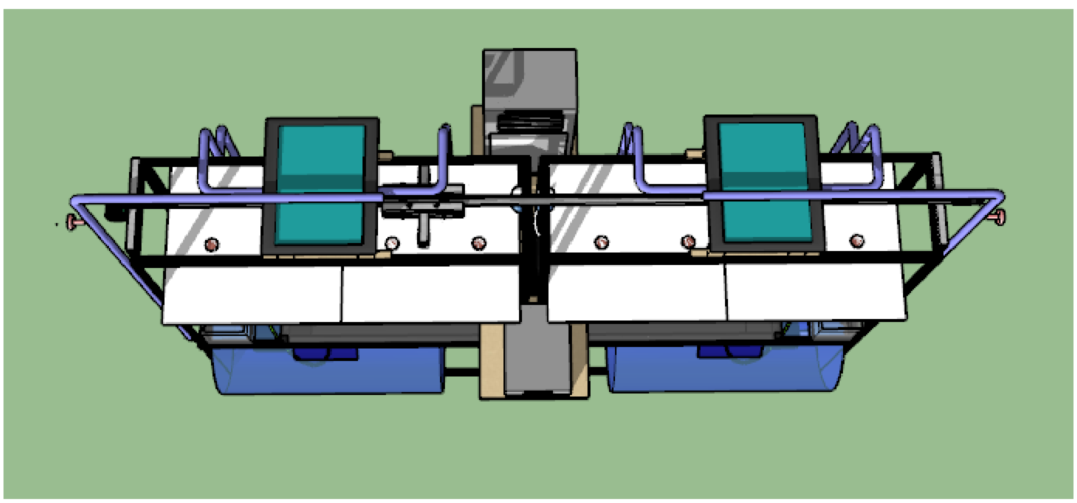


Figure 4.1 Smart Aquaponics inside the Greenhouse



(a)



(b)

Figure 4.2 Smart Aquaponics Set-up

(a) Front View, (b) Top View

The whole system was powered by two 265 W and three 120 W solar panels connected to three solar charge controllers and six 12V solar batteries. An inverter was connected for the AC powered correcting devices such as fans and air cooler. The system was using one water pump for the continuous circulation of water. The water in the fish tank was pumped to the filter, flowed down the two grow beds, flowed through the sump tank and was flushed back to the fish tank through gravity. A valve attached with the pipes controlled the amount of water flow circulating the aquaponics.

4.2 Project Structural Organization

4.2.1 Actual Aquaponics Set-up

Figure 4.3 Actual Greenhouse

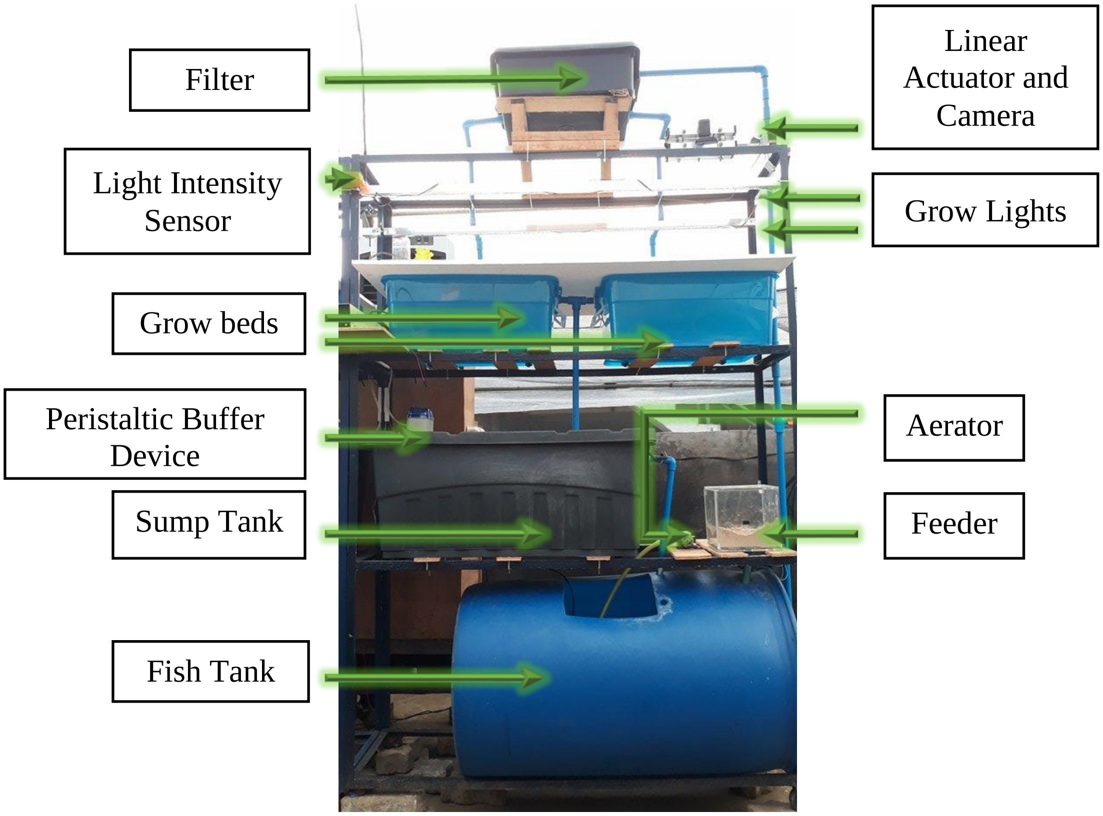


Figure 4.4 Parts of the Actual Aquaponics Set-up

Figure 4.5 Actual Aquaponics Set-up with Battery Box and Air Cooler

Figure 4.3 shows the actual aquaponics set-up inside the greenhouse. Attached are the inlet fans at the top of the greenhouse door and the exhaust fan at the far end of the greenhouse. In between the two inlet fans is the air temperature sensor.

The parts of a single set-up of the smart aquaponics are shown in Figure 4.4. The trellis of the set-up primarily contained a filter, two grow beds, a sump tank and a fish tank. At the top of the grow beds where the grow lights and the linear actuator with web camera were fixed on the trellis. The sump tank contained the ISFET sensor. The peristaltic buffer device was connected with the sump tank through a hose where the $CaCO_3$ was being released. At the top of the fish tank are the automatic feeder that drops food for the fishes, and the aerator correcting device that had its hose submerged in the fish tank's water. The fish tank also contained the water temperature sensor inside.

As shown in Figure 4.5, behind the aquaponics set-up was the air cooler at the top of the battery box. Inside the box contained all batteries connected to the solar panels. Figure 4.6 shows the solar panels near the greenhouse.

Figure 4.6 Actual Solar Panels

4.2.2 Screenshots of AquaDroid V2.0 Application

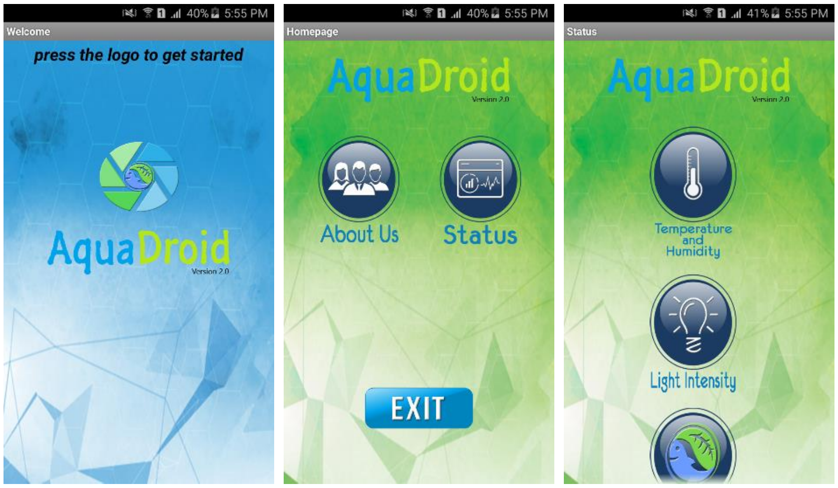


Figure 4.7 Main User Interface

Figure 4.7 shows of the home page of the AquaDroid V2.0 application. All the pages of the android application can be opened from the main interface.

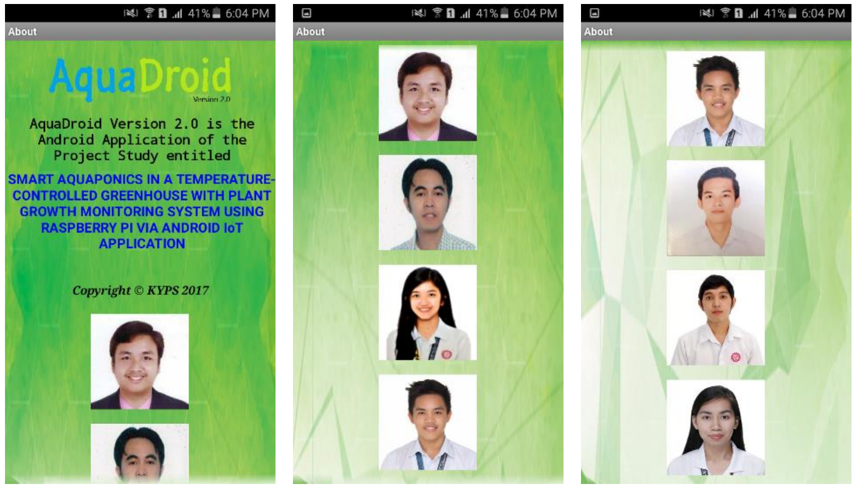


Figure 4.8 Proponents' Profile UI

Figure 4.8 shows the About page of the AquaDroid V2.0 application. The title of the study and the authors are shown here.

Figure 4.9 Parameter Status Page

Figure 4.9 shows the parameter status page of the AquaDroid V2.0 application. This page visualized the data monitoring of specific aquaponics parameter including the real-time data visualization and chronological data monitoring through graph representation.

4.3 Project Limitations and Capabilities

The project was limited in comparing the plant growth of the smart aquaponics from the conventional soil-based farming, and limited in historical comparison of the fish growth between the smart aquaponics system and the aquaponics from a related past study entitled, *Development of Solar-Powered Arduino-based Smart Aquaponics System through Android IoT Application* by Lapuz et.al.

The limitations of the project were as follows:

1. The system can only monitor the light intensity, air temperature, pH level parameters, and water temperature.
2. The system were limited for the growth of pechay, lettuce, mustasa, and tilapia fish.
3. The growth monitoring was limited to acquiring the projected surface area of the plant through Python image processing program. Its accuracy was evaluated through comparison with Easy Leaf Area Software.

4.4 Project Evaluation

4.4.1 Air Temperature Evaluation Results and Discussion

Table 4.1 Experimental Data for Conventional Digital Thermometer and DHT11 Air Temperature Sensor

Trial	Conventional Digital Thermometer	DHT11 Temperature Sensor
	°C	°C
1	30.1	30.0
2	30.1	30.0
3	30.2	30.0
4	30.2	30.0
5	30.4	30.0
6	30.5	30.0

7	30.6	31.0
8	30.6	31.0
9	30.5	31.0
10	30.5	31.0
11	29.8	30.0
12	29.8	29.0
13	29.8	29.0
14	29.9	30.0
15	30.0	30.0
16	30.0	30.0
17	30.0	30.0
18	30.1	30.0
19	29.9	30.0
20	29.9	29.0

Table 4.1 shows the readings conventional digital thermometer and DHT11 air temperature sensor. For statistical test, the mean the data for 20 trials were also initially calculated.

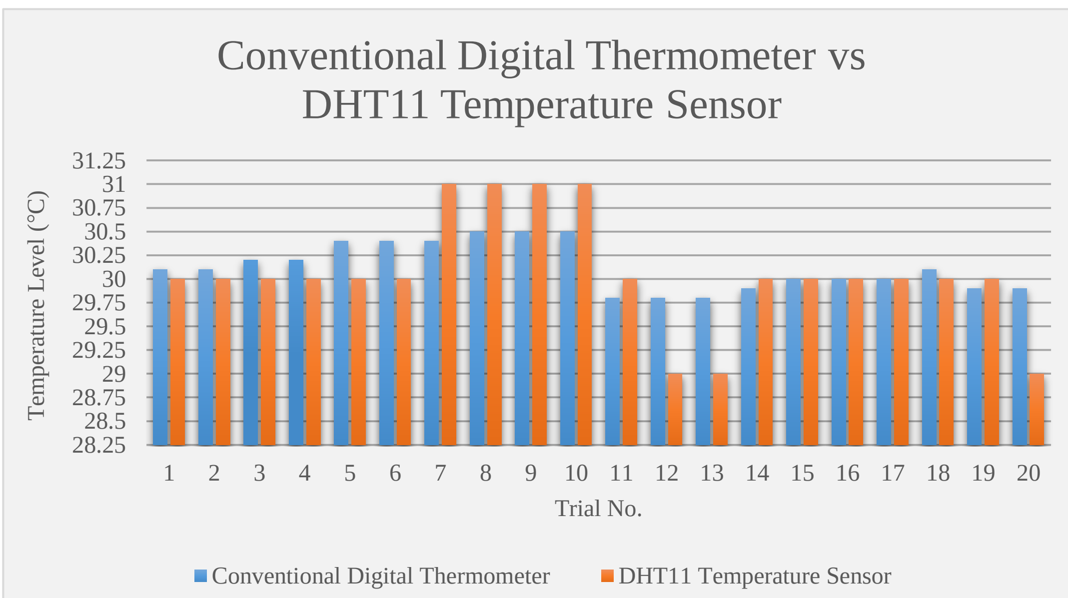


Figure 4.10 Conventional Digital Thermometer vs DHT11 Air Temperature Sensor

Figure 4.10 shows the mean of the DHT11 air temperature sensor has closely similar linear trend line with the conventional digital thermometer. Both are subjected to trials with varying temperature at the same testing time. It was seen that the DHT11 sensor displays more precise values than the digital thermometer. Therefore, the DHT11 air temperature was proven accurate.

4.4.1.1 Statistical Analysis of Conventional Digital Thermometer and DHT11 Air Temperature Sensor Experimental Data

The two sensors' readings were compared by undergoing statistical data analysis using paired t-test. This test was utilized since the observation of the first sample can be paired with the observation of the other. The null hypothesis Ho was set that there is no significant difference between conventional digital thermometer and DHT11 air temperature sensor. The level of significance was set to 0.01. The paired t-tests were executed following the formulae:

$$d_i = y_i - x_i \qquad (1)$$

$$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \qquad (2)$$

$$SE(\bar{d}) = \frac{s_d}{\sqrt{n}} \qquad (3)$$

$$T = \frac{\bar{d}}{SE(\bar{d})} \qquad (4)$$

where y_i and x_i were the sample observation on each pair, SE was the standard deviation of the differences, T was the t-statistic with n-1 degrees of freedom.

Table 4.2 Paired T-test for Air Temperature

SUMMARY			Alpha	0.01		Hyp Mean Diff	0	
Groups	*Count*	*Mean*	*Std Dev*	*Std Err*	*t*	*df*	*Cohen d*	*Effect r*
Conventional Digital Thermometer	20	30.125	0.248945					
DHT11 Temperature Sensor	20	30.05	0.604805					
Difference	20	0.075	0.433923	0.097028	0.772971	19	0.172842	0.174608

T TEST					
	p-value	*t-crit*	*lower*	*upper*	*sig*
One Tail	0.224525	2.539483			no
Two Tail	0.449049	2.860935	-0.20259	0.352591	no

In summary as shown in Table 4.2, the conventional digital thermometer and the DHT11 temperature sensor were compared. The p-value is greater than the 0.01 which meant that there is no significant difference between the means of the two devices. This signifies that the DHT11 sensor's accuracy is acceptable.

4.4.2 Light Intensity Evaluation Results and Discussion

Table 4.3 Experimental Data for Conventional Light Intensity Meter and BH1750FVI Light Intensity Sensor

Trial	Conventional Light Intensity Meter	BH1750FVI Light Intensity Sensor
	(lux)	(lux)
1	138	138
2	140	139
3	137	137
4	135	136
5	132	133

6	1310	1293
7	1370	1373
8	1420	1428
9	1410	1325
10	1460	1458
11	1500	1510
12	1530	1528
13	1530	1525
14	1540	1535
15	1550	1554
16	1610	1615
17	1640	1636
18	1670	16880
19	1640	1655
20	1710	1700

Table 4.3 showed all the recorded light intensity readings of the conventional light intensity meter with the BH1750FVI light intensity sensor. 20 trials were acquired for statistical testing.

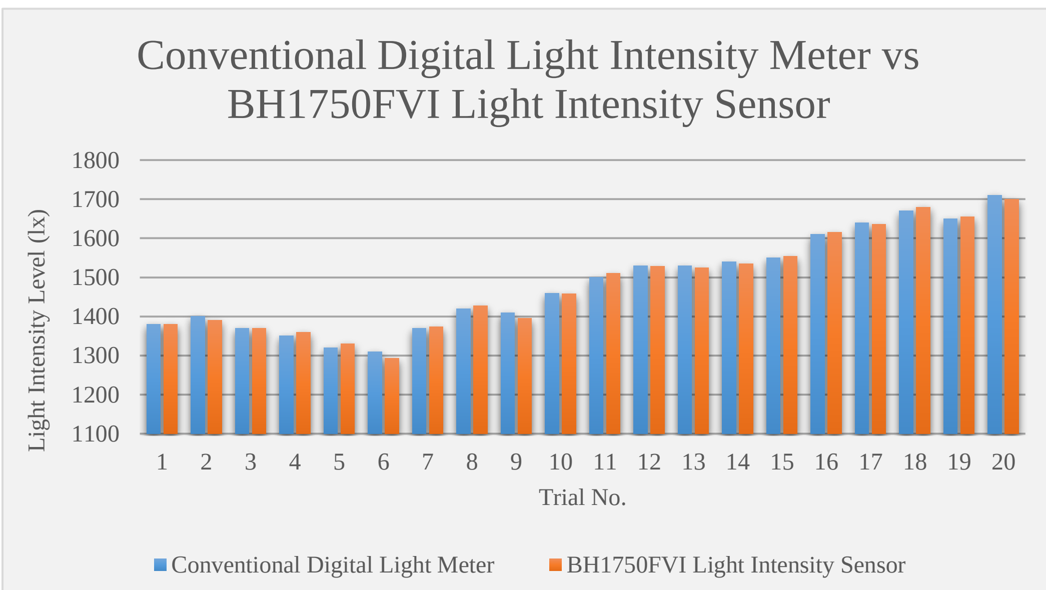


Figure 4.11 Conventional Light Intensity Meter vs BH1750FVI Sensor

The graph in Figure 4.11 shows the result of the BH1750FVI light intensity sensor when compared to a conventional digital thermometer to test the accuracy. Under 20 trials, two devices were subjected to different light intensity at the same testing time. It was seen that the overlapping trend lines in the graph manifest that the two were almost equal. The two devices shown almost the same equations. This attests that there is no significant difference on the readings between the two devices. Therefore, the BH1750FVI light intensity sensor was proven accurate.

4.4.2.1 Statistical Analysis of Conventional Digital Thermometer and BH1750FVI Light Intensity Sensor Experimental Data

The two sensors' readings were compared by undergoing statistical data analysis using paired t-test. This test was used also in this experimental data since the observation of the first sample can also be paired with the observation of the other. The null hypothesis Ho was set that there is no significant difference between conventional light intensity meter and BH1750FVI light intensity sensor. The level of significance was set to 0.01. The paired t-tests were executed with the same formulae as shown in Equation 4.1, Equation 4.2, Equation 4.3, and Equation 4.4.

Table 4.4 Paired T-test for Light Intensity

SUMMARY			Alpha	0.01		Hyp Mean Diff	0		
Groups	*Count*	*Mean*	*Std Dev*	*Std Err*	*t*	*df*	*Cohen d*	*Effect r*	
Conventional Digital Light Meter	20	1486	124.4948						
BH1750FVI Light Intensity Sensor	20	1485.75	125.3596						
Difference	20	0.25	8.353222	1.867837	0.133845	19	0.029929	0.030692	

T TEST					
	p-value	*t-crit*	*lower*	*upper*	*sig*
One Tail	0.447466	2.539483			no
Two Tail	0.894933	2.860935	-5.09376	5.59376	no

In summary as shown in Table 4.4, the conventional digital light meter and the BH1750FVI light intensity sensor were compared. The p-value is greater than 0.01 which means that there is no statistically difference between the means of the two devices. This signifies that the BH1750FVI sensor's accuracy is acceptable.

4.4.3 Python Image Processing Evaluation Results and Discussion

Table 4.5 Experimental Data for Python Image Processing Program and Easy Leaf Area Software

Trial	Python Image Processing Program	Easy Leaf
	(cm^2)	(cm^2)
1	102.3	101.4
2	60.98	59.87
3	93.3	94.15
4	57.44	57.86
5	132.94	133.02
6	83.09	84.03
7	75.54	75.56
8	27.36	25.79
9	116.78	120.42
10	74.71	75.69
11	99.04	98.22
12	69.44	72.70
13	170.93	172.05
14	90.65	89.76

15	108.94	110.89
16	38.47	36.73
17	192.03	190.89
18	109.18	111.98
19	129.6	130.28
20	104.52	105.13

To test the acceptability of the Python Image Processing Program, a comparison was done with a software that provides an accurate, free and rapid tool to estimate leaf area from digital images. Table 4.4 showed all the recorded surface area measurement readings from the Python image processing program and the Easy Leaf Area software. 20 trials were acquired for statistical testing to determine the acceptability and accuracy of the Python image processing program.

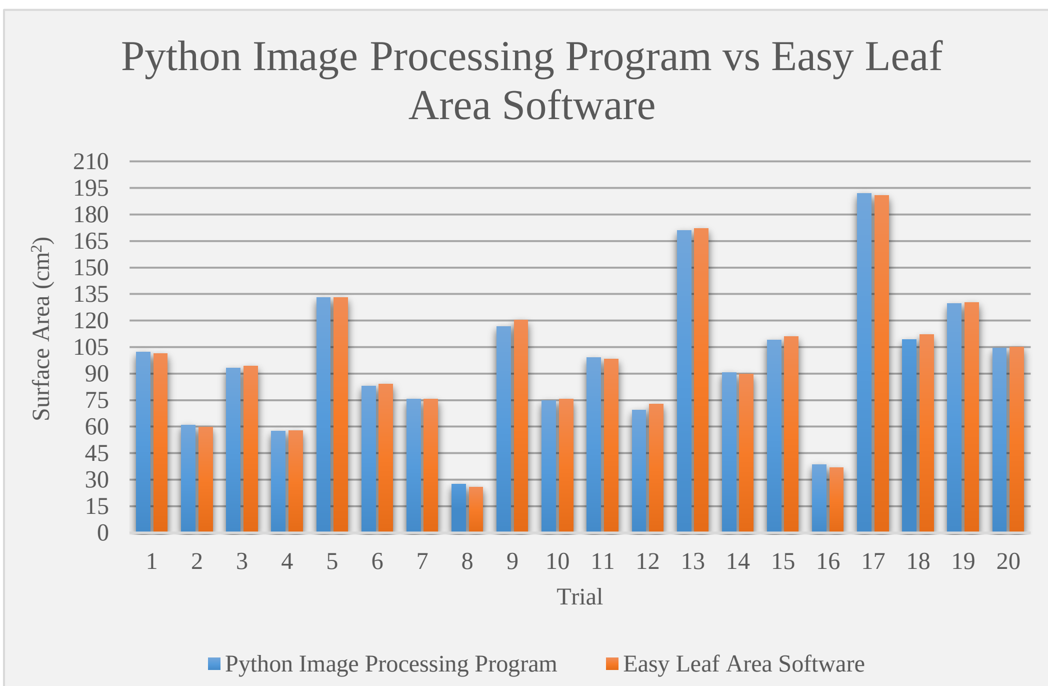


Figure 4.12 Python Image Processing Program vs Easy Leaf Area Software

The graph in Figure 4.12 shows the result of the Python Image Processing Program and the Easy Leaf Area Software to test the program's accuracy. Under 20 trials of measuring different plant area, it was manifested that the reading from both were almost equal.

4.4.3.1 Statistical Analysis of Python Image Processing Program and Easy Leaf Area Software Experimental Data

Using student's t-test or independent two-sample t-test assuming equal variances and assuming unequal variances, the acceptability of the Python image processing program was evaluated. For the following hypotheses for this study, null hypothesis indicates there is no significant difference between the Python image processing program and the Easy Leaf Area software. The level of significance was set to 0.01.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \qquad (5)$$

$$s_p = \sqrt{\frac{(n_1 - 1)\, s_{X_1}^2 + (n_2 - 1)\, s_{X_2}^2}{n_1 + n_2 - 2}}. \qquad (6)$$

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{\Delta}}} \qquad ($$

$$s_{\bar{\Delta}} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}.$$

(8)

where t in Equation 4.5 is the t-statistic for unequal variances, s_p in Equation 4.6 is the pooled standard deviation for unequal variances, t in Equation 4.7 is the t-statistic for equal variances, and s of Equation 4.8 is the standard deviation for equal variances.

Table 4.6 Student's T-test for Image Processing

SUMMARY			Hyp Mean Diff	0
Groups	*Count*	*Mean*	*Variance*	*Cohen d*
Python Image Processing Program	20	96.862	1617.038	
Easy Leaf Area Software	20	97.321	1644.763	
Pooled			1630.901	0.011366

T TEST: Equal Variances				Alpha	0.01				
	std err	*t-stat*	*df*	*p-value*	*t-crit*	*lower*	*upper*	*sig*	*effect r*
One Tail	12.7707	0.035942	38	0.485758	2.428568			no	0.00583
Two Tail	12.7707	0.035942	38	0.971517	2.711558	-35.0874	34.16941	no	0.00583

T TEST: Unequal Variances				Alpha	0.01				
	std err	*t-stat*	*df*	*p-value*	*t-crit*	*lower*	*upper*	*sig*	*effect r*
One Tail	12.7707	0.035942	37.99725	0.485758	2.428575			no	0.005831
Two Tail	12.7707	0.035942	37.99725	0.971517	2.711568	-35.0875	34.16955	no	0.005831

In summary as shown in Table 4.5, the Python image processing program and Easy Leaf Area software were compared. The p-value is greater than 0.01 which means that there is no statistically difference between the means of the surface area acquired from Python image processing program and Easy Leaf Area software. This signifies that the Python image processing program is acceptable for its accuracy.

4.4.4 Comparison of Lengths and Weights of Plants and Fish from the Present Smart Aquaponics System and Smart Aquaponics from Related Past Study

4.4.4.1 Growth of Monitored Tilapia Fish for Three Months

Table 4.7 Average Length of Fish per Tank Every Two Weeks

Day Lapsed	Average Length per Tank (in)		Improvement Rate
	Present System	Past System	
14	3.87	3.91	-1.02%
28	4.9	4.87	0.61%
42	5.19	5.04	2.97%
56	5.51	5.32	3.57%

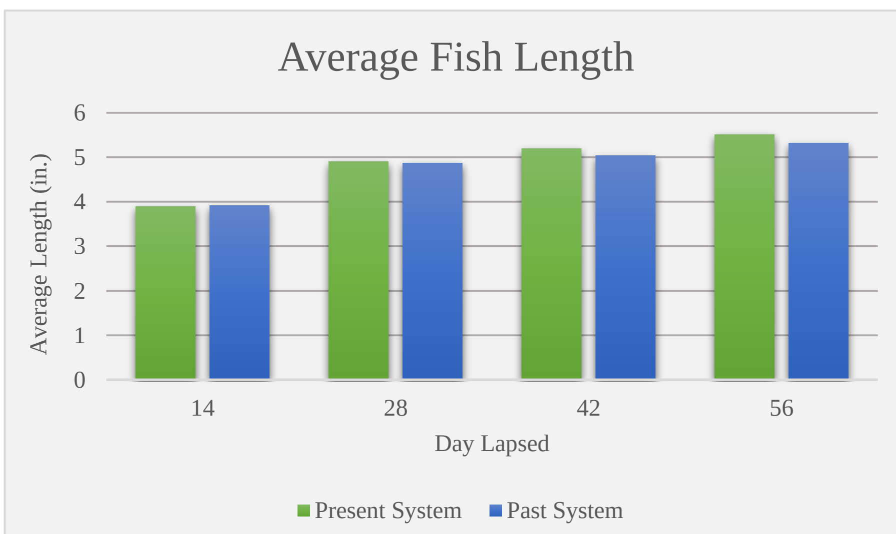


Figure 4.13 Average Fish Length for Each Aquaponics System

The lengths of all the fish in the set-ups were measured in inches using a foot rule. There was a total of ten fish per setup and all of which started from a 4-inch size. Measurements were done every two weeks to see the significant growth of the fish in terms of length. It was seen that the fish were measured for 4 times as shown in table 4.6. The average length of fish per setup was calculated. In comparison with the historical data of the past related study, it was seen in Figure 4.13 that the fish in present aquaponics setup significantly grew faster than the data of the past related study.

Table 4.8 Average Weight of Fish per Tank Every Two Weeks

Day Lapsed	Average Weight per tank (g)		Improvement Rate
	Present System	Past System	
14	25.8	26.2	-1.53%
28	45.25	40.1	12.84%
42	54.9	52.1	5.37%
56	65.85	63.11	4.34%

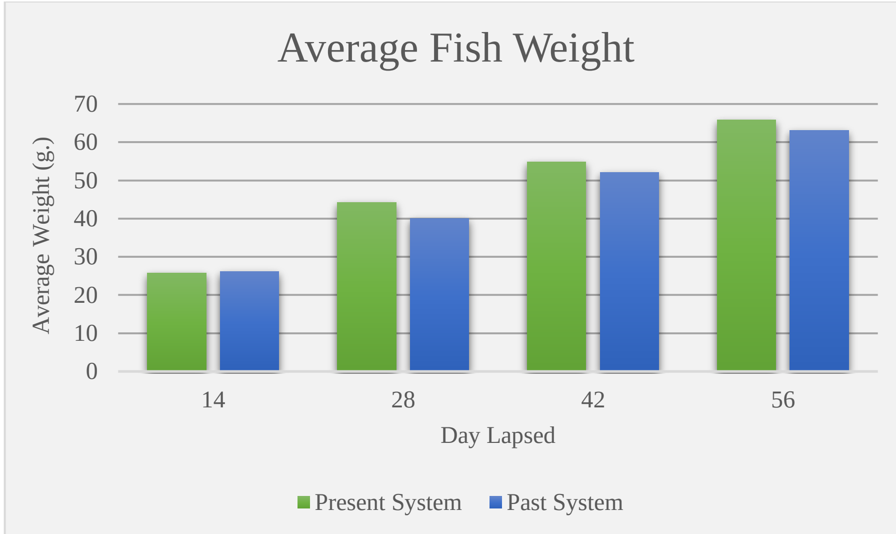


Figure 4.14 Average Fish Weight of Each Aquaponics System

The weight of all the fish in the systems were measured in grams. As seen in table 4.7, it was shown that the fish were weighed for 4 times Also, measurements were done every two weeks to see the significant growth of the fish in terms of weight starting from day 42 (6 weeks) of the fishes. The weights of the fish were measured using a digital weighing scale and the average weight in each system was calculated. In comparison with the historical data of the past related study, it was seen in Figure 4.14 that the fish in present aquaponics setup significantly grew faster terms of weight than the data of the past related study.

4.4.4.2 Comparison of Surface Area of Plants between Aquaponics System and Conventional Soil-based Farming

Table 4.9 Average Surface Area of Pechay Grown in Aquaponics System and Conventional Soil-based Farming Every Week

Pechay		
Day Lapsed	Surface Area (cm^2)	
	Aquaponics System	Conventional Farming
21	81.64	4.49
28	95.75	4.85
35	150.61	7.49

For the aquaponics set-up, the pechay plants started as seeds grown in a Styrofoam box to become seedlings. The seedlings were transferred from the box to grow beds after three weeks. For the conventional soil-based farming, pechay seeds were directly planted to a Styrofoam box filled with soil and remained for plant growth monitoring. For the two different experimental set-up, the surface area of each plant was measured using vision-based plant growth monitoring of the system through image processing. Table 4.6 shown that plant measuring were done every week within three weeks and the average area of each test system was calculated to see their significant differences. It was observed that the pechay grown in the smart aquaponics system had the greater growth than the pechay grown in conventional soil-based farming as shown in Figure 4.15

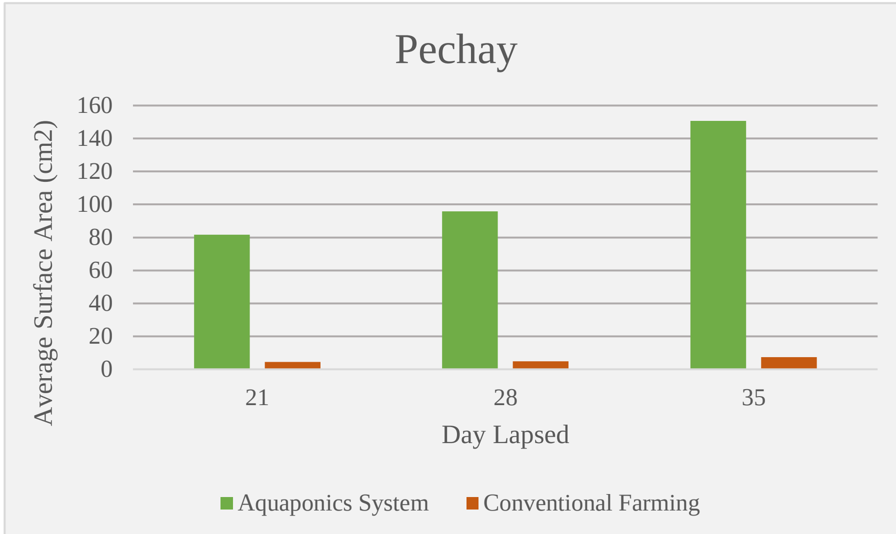


Figure 4.15 Surface Area of Pechay for the Two Experimental Set-ups

Table 4.10 Average Surface Area of Lettuce Grown in Aquaponics System and Conventional Soil-based Farming Every Week

Lettuce		
Day Lapsed	Surface Area (cm^2)	
	Aquaponics System	Conventional Farming
21	91.70	10.27
28	107.52	13.61
35	151.20	30.94

For the aquaponics set-up The Lettuce plants started as seeds grown in a Styrofoam box to become seedlings. After three weeks, the seedlings were ready to be transplanted from the box to grow beds. For the conventional soil-based farming, lettuce seeds were directly planted to a Styrofoam box filled with soil and remained for plant growth monitoring.

In all set-ups, the surface area of each plant was measured using vision-based plant growth monitoring of the system through image processing. Plant measuring were done every week within three weeks and the average area of all the lettuce plants each test system was calculated to see their significant differences as shown in Table 4.9.

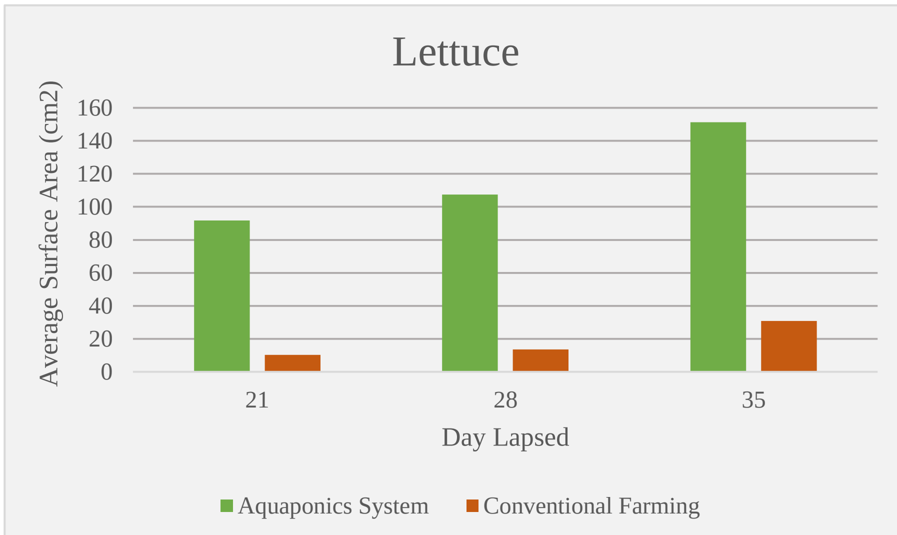


Figure 4.16 Surface Area of Lettuce for the Two Set-ups

It was observed that the lettuces grown in the smart aquaponics system had the greater growth than the lettuces grown in conventional soil-based farming as shown in Figure 4.16.

Table 4.11 Average Surface Area of Mustasa Grown in Aquaponics System and Conventional Soil-based Farming Every Week

Mustasa		
Day Lapsed	Surface Area (cm^2)	
	Aquaponics System	Conventional Farming
21	51.45	7.6
28	73.71	9.18
35	97.86	10.79

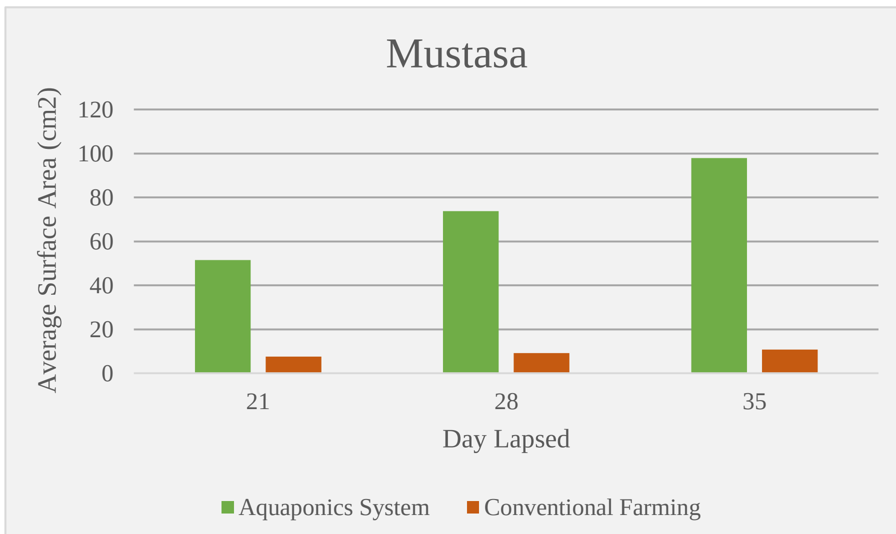


Figure 4.17 Surface Area of Mustasa for the Two Set-ups

For the aquaponics set-up, the mustasa seeds were planted in a Styrofoam box to become seedlings. When the seedling were ready for transplanting after three weeks, seedlings were transferred from the box to grow beds. For the conventional soil-based farming, mustard seeds were directly planted to a Styrofoam box filled with soil and remained for plant growth monitoring. The surface area of each plant on both set-ups was measured using vision-based plant growth monitoring of the system through image processing. Within three weeks, plant measuring were done every week as shown in Figure 4.17. In order see their significant differences, average area of each set-up was calculated. It was observed that the mustasa grown in the smart aquaponics system had the greater growth than the mustasa grown in conventional soil-based farming.

Using student’s t-test or independent two-sample t-test assuming equal variances and assuming unequal variances, the growth of plants in the smart aquaponics specifically, pechay, lettuce, and mustasa, was evaluated. For the following hypotheses for this study, null hypothesis indicates there is no significant difference between the surface area of the plants grown in the smart aquaponics system, and the surface area of the plants grown in conventional soil-based farming. The level of significance was set to 0.01.

Table 4.11 Student's T-test for the Surface Area of the Plants

SUMMARY			Hyp Mean Diff	0
Groups	*Count*	*Mean*	*Variance*	*Cohen d*
Aquaponics System	24	104.3175	2725.254	
Conventional Soil-based Farming	24	12.83583	96.10664	
Pooled			1410.68	2.435677

T TEST: Equal Variances				Alpha	0.01				
	std err	*t-stat*	*df*	*p-value*	*t-crit*	*lower*	*upper*	*sig*	*effect r*
One Tail	10.84236	8.437434	46	3.38E-11	2.410188			yes	0.779407
Two Tail	10.84236	8.437434	46	6.76E-11	2.687013	62.34811	120.6152	yes	0.779407

T TEST: Unequal Variances				Alpha	0.01				
	std err	*t-stat*	*df*	*p-value*	*t-crit*	*lower*	*upper*	*sig*	*effect r*
One Tail	10.84236	8.437434	24.62018	4.39E-09	2.485107			yes	0.861993
Two Tail	10.84236	8.437434	24.62018	8.78E-09	2.787436	61.25929	121.704	yes	0.861993

In summary as shown in Table 4.11, the surface area of the plants grown in the smart aquaponics system, and the surface area of the plants grown in conventional soil-based farming were compared. The p-value is less than 0.01 which means that there is a significant difference between the surface areas acquired from the two experimental set-up. This signifies that the smart aquaponics system produced an optimum crop yield than the conventional soil-based farming.

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

Integrating of monitoring and correcting devices greatly affected the whole system principally to growth of plants and fishes. Considering the surrounding of around the aquaponics system, light intensity and air temperature showed accurate readings for the monitoring of the environmental parameters. Also, traditional way of inspecting growth and direct measuring of plants needs great labor, becomes time-consuming and destructive at times. It gives a high error due to variation of visual perceptions. An advancement to growth monitoring on aquaponics system is needed to eliminate traditional destructive way of measuring plants. Based on the data gathered and evaluated, the plant growth monitoring system using Python image processing program showed accuracy with comparison to Easy Leaf Area software. In support to these, the plants were grown in smart aquaponics system and were assessed by its surface area using Python image processing program to assess the promising effectivity of aquaponics compared to conventional soil-based way of planting. Moreover, the weight of the fishes were monitored also to attest the system's effectivity compared to related aquaponics study entitled, Development of Solar-Powered Arduino-based Smart Aquaponics System through Android IoT Application, by Lapuz et.al.

5.2 Conclusions

This study was proposed to develop of a self-sustainable smart aquaponics system in a temperature-controlled greenhouse made Android IoT monitoring and automatic correction, and plant growth monitoring system using Raspberry Pi. This project was seeking to respond crucial food safety in rising population of busy urban areas while attaining solution towards environment impact in the Philippines. In line with these, the study focused on proving the acceptability of the Python image processing program in comparison with the Easy Leaf Area software. Measurements acquired from the both software were subjected to student's t-test after assessing under series of trials. As a result, readings from the Python image processing program has statistically no difference compared to the Easy Leaf area software indicating the program's acceptability for accurate measuring. With a reliable proof, the sustainable smart aquaponics system shown better results in terms of growth of plants and fishes. The average weight and length of tilapia grown in this research showed greater growth rate in historical comparison with the average weight and length of tilapia grown from a particular related study. Plant growth rate from this research indicated affirmative results compared to plant growth rate from conventional soil-based farming.

Successful implementation of whole aquaponics monitoring system was made through web database and user-friendly Android application. Thus, giving the user ease of access in monitoring the smart aquaponics in any place and time with IoT gateway.

5.3 Recommendations

The proponents of the study endorse to persist developing the study in terms of its the plant growth monitoring system capabilities. The enhancement of image processing to further assess other different plant features is recommended. Providing additional solar panels is advised to not only cover the total power consumption, but also to maintain extra power in case of volatile weather conditions affecting the power generation of the system. Expansion of monitoring and correcting device varieties is recommended for better yield production.

References

(n.d.). Retrieved from OriginLab Corporation: https://d2mvzyuse3lwjc.cloudfront.net/images/WikiWeb/Programming_page/PyOrigin_Module.png?v=1856

(n.d.). Retrieved from Open Builds Part Store: http://openbuildspartstore.com/v-slot-nema-17-linear-actuator-bundle-belt-driven/

(2009). Retrieved from Aquaponics How To: https://www.ripplingwaterscharity.org/wp-content/uploads/2016/11/diagram.jpg

(2012, October). Retrieved from Herbs form Wales.

(2015). Retrieved from Federal Trade Commision: https://www.ftc.gov/system/files/documents/reports/federal-trade-commission-staff-report-november-2013-workshop-entitled-internet-things-privacy/150127iotrpt.pdf

(2016). Retrieved from Makerlab Electronics: https://www.makerlab-electronics.com/product/waterproof-temperature-sensor-ds18b20/

Adafruit. (n.d.). *Raspberry Pi 3 - Model B - ARMv8 with 1G RAM*. Retrieved from Adafruit: https://www.adafruit.com/product/3055

Agarwal, T. (2015). *Ion Sensitive Field-Effect Transistor – ISFET Working Principle*. Retrieved from ELPROCUS: https://www.elprocus.com/ion-sensitive-field-effect-transistor-isfet-working-principle/

Agarwal, T. (2015). *Know about Different Types of Sensors with their Applications*. Retrieved from EDGEFX.in: https://www.edgefx.in/different-types-of-sensors-with-applications/

Albert, S. (2017). *Harvest to Table*. Retrieved from Google: https://www.harvesttotable.com/how_to_grow_lettuce/

Albert, S. (2017, February 12). *How to Grow Lettuce*. Retrieved from Harvest to Table.

Aquaponics Guideliness. (2015, August).

Arduino. (2017, January). *Arduino Mega*. Retrieved from Arduino.cc: https://www.arduino.cc/en/Main/ArduinoBoardMega

Arduino Mega. (2017). Retrieved from Arduino: https://www.arduino.cc/en/uploads/Main/ArduinoMega.jpg

BH1750 Light Intensity Sensor. (2017). Retrieved from Addicore: https://www.addicore.com/BH1750FVI-p/ad290.htm

Burgess, M. (1999). *C Programming Tutorial*.

Circuit Basics. (2015). *HOW TO SET UP THE DHT11 HUMIDITY SENSOR ON AN ARDUINO*. Retrieved from Circuit Basics: http://www.circuitbasics.com/how-to-set-up-the-dht11-humidity-sensor-on-an-arduino/

Computer Hope. (2017, October 2). *Webcam*. Retrieved from Computer Hope: https://www.computerhope.com/jargon/w/webcam.htm

Connolly, K., & Trebic, T. (2010, April 14). *Biosource Engineering.* Retrieved from McGill: https://www.mcgill.ca/bioeng/files/bioeng/KeithTatjana2010.pdf

Deal Extreme. (2016). Retrieved from Google: http://www.dx.com/p/dht11-digital-temperature-humidity-sensor-module-for-arduino-single-bus-blocks-316867#.WUZIH4yGPIU

Diver, S. (2006). Aquaponics—Integration of Hydroponics with Aquaculture. *ATTRA—National Sustainable Agriculture Information Service*.

Dr Kline, C. (2008, June 10). *Easy Lettuce Growing with a Raft Aquaponic System*. Retrieved from Garden and Greenhouse: http://www.gardenandgreenhouse.net/articles/november-december-2008/easy-lettuce-growing-with-a-raft-aquaponic-garden/

Electronic Component. (n.d.). Retrieved from Ali Express: https://www.aliexpress.com/store/product/5x-SONGLE-SRA-5VDC-CL-DC5V-

20A-PCB-General-Purpose-Relay-5-Pins-SRA-05VDC-CL/1226120_32760531590.html

Electus Distribution. (2001). Retrieved from Learn Bench: http://www.lbenchindia.com/finalyearprojectdatasheets/relaydrv.pdf

English, L. A. (2015). *Economic Feasibility of Aquaponics in Arkansas.* Arkansas: ScholarWorks@UARK.

Fisheries Policy and Economics Division. (2008). *Commodity Commodity ROAD MAP: TILAPIA.* Bureau of Fisheries and Aquatic Resources.

Full-Screen Dialog. (n.d.). Retrieved from ConceptDraw: https://conceptdraw.com/a1046c4/preview

Guerrero III, R. D. (2013). *THe Production and Trade of Tilapia in the Philippines.*

IoT end-to-end demo - Remote Monitoring and Service. (2014, March 24). Retrieved from Oracle: https://blogs.oracle.com/iot/iot-end-to-end-demo-remote-monitoring-and-service

Johnson, B. (2012, August 30). *How the Raspberry Pi Works*. Retrieved from How Stuff Works: https://computer.howstuffworks.com/raspberry-pi.htm

Keith, J. (2012). *555 (TLC555) Relay Driver Circuit*. Retrieved from Electro Schematics.

Knight, D. (2015, November 24). *Buck Converters and Their Cool Applications*. Retrieved from All About Circuits: https://www.allaboutcircuits.com/technical-articles/buck-converters-and-their-cool-applications/

Learn Computational Thinking with MIT App Inventor. (2016, December 15). Retrieved from Coding for Young People: http://codingforyoungpeople.eu/wp-content/uploads/2016/12/appinventor-blocks-1024x454.png

Lee, C.-S., Kim, S. K., & Kim, M. (2009, September 7). Ion-Sensitive Field-Effect Transistor for Biological Sensing. *Sensors*.

Maker Lab Electronics. (2015). Retrieved from https://www.makerlab-electronics.com/product/dc-dc-buck-converter-lm2596s/

Naaman, M., & Peltier, T. (1998, April). FUNDAMENTALS OF REMOTE ACCESS.

North, D. (2016, May 30). *What is Aquaponics and How Does It Work?* Retrieved from Permaculture Reasearch Institute: https://permaculturenews.org/2016/05/30/what-is-aquaponics-and-how-does-it-work/

Power Jacks Limited. (n.d.). *Linear Actuators*. Retrieved from Power Jacks: https://www.powerjacks.com/about-us/how-a-linear-actuator-works

Rakocy, J. E., Bailey, D. S., Shultz, R., & Thoman, E. S. (2004). Update on Tilapia and Vegetable Production in the UVI Aquaponic System. *New Dimensions on Farmed Tilapia: Proceedings of the Sixth International Symposium on Tilapia in Aquaculture, Manila, Philippines*, 676-690.

Rawashdeh, M. (2014). *BH1750 Digital Light Sensor*. Retrieved from instructables: http://www.instructables.com/id/BH1750-Digital-Light-Sensor/

Rogers, R., Lombardo, J., Mednieks, Z., & Meike, B. (2009). *Android Application Development.* Sebastopol: O'Reilly Media, Inc.

Rossana, S. (2016). Important Water Quality Parameters.

Rushworth, J. (2014, July 21). *Which solar charge controller: PWM or MPPT?* Retrieved from Vitron Energy: http://www.lazada.com.ph/oh-solar-regulator-30a-solar-charge-controller-pwm-for-solar-panelbattery-black-4275834.html

Savvas, D., & Passam, H. (2002). *Hydroponic Production of Vegetables and Ornaments.* Athens, Greece: Embryo Publications.

Science Company. (2017). Retrieved from The Science Company Website: https://www.sciencecompany.com/Calcium-Carbonate-500g-P6641.aspx

Sendy, A. (2016, April 4). *Solar Reviews*. Retrieved from Solar Energy: https://www.solarreviews.com/images/solar-energy-solar-panels.png

Sensors: Different Types of Sensors. (2012). Retrieved from EngineersGarage: https://www.engineersgarage.com/articles/sensors

Singh, R. (2014). An Overview of Android Operating System and Its Security. *International Journal of Engineering Research and Applications* , 519-521.

Somerville, C., Cohen, M., Pantanella, E., Stankus, A., & Lovatelli, A. (2014). Small-scale Aquaponic Food Production Integrated Fish and Plant Farming. *FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER*.

Storey, A. (2016, July 29). *Get the Tips & Guidelines on Growing Mustard Greens*. Retrieved from Upstart University: https://university.upstartfarmers.com/blog/get-the-tips-guidelines-on-growing-mustard-greens

Storey, A. (2016, July 22). *Here's What You Need to Know About Growing Bok Choy in Hydroponics*. Retrieved from Upstart University: https://university.upstartfarmers.com/blog/heres-what-you-need-to-know-about-growing-bok-choy-in-hydroponics

(2017). *The Basics of Breeding Tilapia for Aquaponics.*

The Environmental Importance of the Different Impairment. (2011). Retrieved from Washington State Department of Ecology: http://www.ecy.wa.gov/programs/wq/images/tmdl/ph_scale.jpg

Thorarinsdottir, R. (2015, August). AQUAPONICS GUIDELINES. p. 36.

Thorarinsdottir, R. (2015, August). AQUAPONICS GUIDELINES. pp. 35-36.

University of Wisconsin. (2006). Dissolved Oxygen: Aquatic Life Depends on It. Wisconsin.

Wade, H. (2003). *Solar Photovltaic System* . Bangalore: United Nations Educational,.

Wang, D., Zhao, J., Huang, L., & Xu, D. (2015). Design of A Smart Monitoring and Control System for Aquaponics Based on OpenWrt. *5th International Conference on Information Engineering for Mechanics and Materials.* Atlantis Press.

Waterproof DS18B20 Digital Temperature Sensor + Extras. (2017). Retrieved from Adafruit : https://www.adafruit.com/product/381

What is an Inverter? (2013, October 31). Retrieved from Electrical Engineering Community: http://engineering.electrical-equipment.org/electrical-distribution/what-is-an-inverter.html

Winsense Co., L. (2013). *Products & Services*. Retrieved from Winsense: http://winsense.co.th/item/item_2.html

Wolber, D., Abelson, H., Spertus, E., & Looney, L. (2011). *App Inventor*. Sebastopol: O'Reilly Media, Inc.

Woodford, C. (2017, June 2). *Webcams*. Retrieved from Explain that Stuff!: http://www.explainthatstuff.com/webcams.html

Yu-Hui, F. Y., Tsung-Cheng, L., Ting-Yu, L., Chang-Chih, L., Wei-Chang, C., & Ta-Te, L. (2013). An Automatic Vision-Based Plant Growth Measurement System for Leafy Vegetables. *Biosystems Engineering*, 43-50.

Connolly, K., & Trebic, T. (2010, April 14). Biosource Engineering. Retrieved from McGill: https://www.mcgill.ca/bioeng/files/bioeng/KeithTatjana2010.pdf

English, L. A. (2015). *Economic Feasibility of Aquaponics in Arkansas.* Arkansas: ScholarWorks@UARK.

Rakocy, J. E., Bailey, D. S., Shultz, R., & Thoman, E. S. (2004). *Update on Tilapia and Vegetable Production in the UVI Aquaponic System.* New Dimensions on Farmed Tilapia: Proceedings of the Sixth International Symposium on Tilapia in Aquaculture, Manila, Philippines, 676-690.

Savvas, D., & Passam, H. (2002). *Hydroponic Production of Vegetables and Ornaments. Athens, Greece: Embryo Publications.*

Wang, D., Zhao, J., Huang, L., & Xu, D. (2015). *Design of A Smart Monitoring and Control System for Aquaponics Based on OpenWrt*. 5th International Conference on Information Engineering for Mechanics and Materials. Atlantis Press.

Yu-Hui, F. Y., Tsung-Cheng, L., Ting-Yu, L., Chang-Chih, L., Wei-Chang, C., & Ta-Te, L. (2013). *An Automatic Vision-Based Plant Growth Measurement System for Leafy Vegetables. Biosystems Engineering, 43-50.*

Suk, J., Kim, S., Ryoo, I. (2011). *Non-Contact Plant Growth Measurement Method and System Based on Ubiquitous Sensor Network Technologies*. Sensors 2011, 11, 4312-4334. doi: 10.3390/s110404312

W. C. Tai et al. (2017). *Development of a Multi-parameter Plant Growth Monitoring and Control System for Quality Agriculture Application*. 2017 International Conference on Applied System Innovation (ICASI), Sapporo, 2017, pp. 1130-1133. doi: 10.1109/ICASI.2017.7988218

Rustia, Dan Jeric & Chung, Wen-Yaw. (2016). *A Multi-Functional Remotely Accessible Monitoring and Control System for Optimized Plant Growth.*

Rustia, Dan Jeric & Chung, Wen-Yaw & Hsiang, Hsu-Chia. (2015). *A Web-Based Greenhouse Automatic Control and Monitoring System.*

Bitella, G., Rossi, R., Bochicchio, R., Perniola, M., Amato, M. (2014*). A Novel Low-Cost Open-Hardware Platform for Monitoring Soil Water Content and Multiple Soil-Air-Vegetation Parameters.* Sensors 2014, 14, 19639-19659. doi:10.3390/s141019639

Odema, M., Adly, I., Wahba, A., & Ragai, H. (2018). *Smart aquaponics system for industrial internet of things (IIoT)*. doi:10.1007/978-3-319-64861-3_79

Nagayo, A. M., Mendoza, C., Vega, E., Al Izki, R. K. S., & Jamisola, R. S. (2017). *An automated solar-powered aquaponics system towards agricultural sustainability in the sultanate of oman*. 2017 IEEE International Conference on Smart Grid and Smart Cities, ICSGSC 2017, 42-49. doi:10.1109/ICSGSC.2017.8038547

Murad, S. A. Z., Harun, A., Mohyar, S. N., Sapawi, R., & Ten, S. Y. (2017). *Design of Aquaponics Water Monitoring System Using Arduino Microcontroller*. Paper presented at the AIP Conference Proceedings, 1885. doi:10.1063/1.5002442

Moon, Seung-Mi & Kwon, Sook-Youn & Lim, Jaehyun. (2014). *Minimization of Temperature Ranges between the Top and Bottom of an Air Flow Controlling Device through Hybrid Control in a Plant Factory.* The Scientific World Journal. 2014. 801590. 10.1155/2014/801590.

Ealson, H. M.& Bloom, A. J. (2014). *Easy Leaf Area: Automated Digital Image Analysis for Rapid and Accurate Measurement of Leaf Area*. Applications in Plant Sciences, 2014. 2(7). doi: 10.3732/apps.1400033

Lapuz, K. T. et al. (2017). *Development of Solar-Powered Arduino-based Smart Aquaponics System through Android IoT Application.*

Alcabasa et.al (2017). *IoT-based Microfarm Prototype with Light, Soil Moisture and Temperature Sensors using Arduino as Sensor Node and Raspberry Pi as Gateway and Controlled using a Smartphone Application*

Ibañez, V. (2014). *Development of an Android Application for Power Consumption Management System Using Programmable Toggle Switch*. Proceedings of the World Congress on Engineering and Computer Science 2015, 1.

Amado, Timothy & Valenzuela, Ira & Orillo, John William. (2016). *Horticulture of lettuce (Lactuvasativa L.) using red and blue led with pulse lighting treatment and temperature control in SNAP hydroponics setup.* Jurnal Teknologi. 78. 10.11113/jt.v78.8804.

Valenzuela, I. C. et al. (2017) *Quality assessment of lettuce using artificial neural network*, 2017IEEE 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), Manila, Philippines, 2017, pp. 1-5.

APPENDIX A

Evaluation

DATA GATHERED

Trial	Python Image Processing Program (cm^2)	Easy Leaf Area Software (cm^2)
1	102.3	101.4
2	60.98	59.87
3	93.3	94.15
4	57.44	57.86
5	132.94	133.02
6	83.09	84.03
7	75.54	75.56
8	27.36	25.79
9	116.78	120.42
10	74.71	75.69
11	99.04	98.22
12	69.44	72.70
13	170.93	172.05
14	90.65	89.76
15	108.94	110.89
16	38.47	36.73
17	192.03	190.89
18	109.18	111.98
19	129.6	130.28
20	104.52	105.13

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Adviser

DATA GATHERED

Trial	Conventional Light Intensity Meter (lux)	BH1750FVI Light Intensity Sensor (lux)
1	138	138
2	140	139
3	137	137
4	135	136
5	132	133
6	1310	1293
7	1370	1373
8	1420	1428
9	1410	1325
10	1460	1458
11	1500	1510
12	1530	1528
13	1530	1525
14	1540	1535
15	1550	1554
16	1610	1615
17	1640	1636
18	1670	16880
19	1640	1655
20	1710	1700

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DATA GATHERED

Trial	Conventional Digital Thermometer	DHT11 Temperature Sensor
	°C	°C
1	30.1	30.0
2	30.1	30.0
3	30.2	30.0
4	30.2	30.0
5	30.4	30.0
6	30.5	30.0
7	30.6	31.0
8	30.6	31.0
9	30.5	31.0
10	30.5	31.0
11	29.8	30.0
12	29.8	29.0
13	29.8	29.0
14	29.9	30.0
15	30.0	30.0
16	30.0	30.0
17	30.0	30.0
18	30.1	30.0
19	29.9	30.0
20	29.9	29.0

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DATA GATHERED

December 20, 2017

Fish No.	Tank 1		Tank 2	
	Length (in)	Weight (g)	Length (in)	Weight (g)
1	3.7	20	3.8	24
2	3.8	21	3.8	22
3	3.8	24	3.9	27
4	3.8	22	3.7	24
5	3.9	28	3.8	24
6	4.0	30	4.0	29
7	4.0	29	3.9	28
8	3.9	27	4.0	30
9	4.0	31	3.8	23
10	4.0	27	3.8	26
Average	3.89	25.9	3.85	25.7

	Length	Weight
Tank 1	3.89	25.9
Tank 2	3.85	25.7
TOTAL AVERAGE	3.87	25.8

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DATA GATHERED

January 3, 2017

Fish No.	Tank 1		Tank 2	
	Length (in)	Weight (g)	Length (in)	Weight (g)
1	4.7	38	4.6	36
2	4.8	40	4.6	38
3	4.9	45	4.8	41
4	4.8	43	4.7	45
5	5.1	47	4.9	47
6	5.1	46	5.2	49
7	4.8	44	5.1	46
8	4.9	45	4.9	48
9	4.9	46	5.1	46
10	5.1	47	5.0	47
Average	4.91	44.2	4.89	44.3

	Length	Weight
Tank 1	4.91	44.2
Tank 2	4.89	44.3
TOTAL AVERAGE	4.90	44.25

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DATA GATHERED

January 17, 2017

Fish No.	Tank 1		Tank 2	
	Length (in)	Weight (g)	Length (in)	Weight (g)
1	4.9	52	4.9	50
2	5.0	54	5.0	49
3	5.1	50	5.1	54
4	5.0	49	4.9	56
5	5.4	50	5.3	57
6	5.3	54	5.5	57
7	5.1	51	5.3	59
8	5.3	56	5.2	56
9	5.3	57	5.2	58
10	5.5	59	5.4	60
Average	5.19	54.2	5.18	55.6

	Length	Weight
Tank 1	5.19	54.2
Tank 2	5.18	55.6
TOTAL AVERAGE	5.19	54.9

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DATA GATHERED

January 31, 2017

Fish No.	Tank 1		Tank 2	
	Length (in)	Weight (g)	Length (in)	Weight (g)
1	5.3	58	5.4	59
2	5.3	60	5.6	69
3	5.5	65	5.5	66
4	5.3	63	5.4	64
5	5.7	69	5.5	65
6	5.5	67	5.7	68
7	5.2	67	5.6	69
8	5.4	66	5.4	65
9	5.7	68	5.8	70
10	5.7	70	5.7	69
Average	5.46	65.3	5.56	66.4

	Length	Weight
Tank 1	5.46	65.3
Tank 2	5.56	66.4
TOTAL AVERAGE	5.51	65.85

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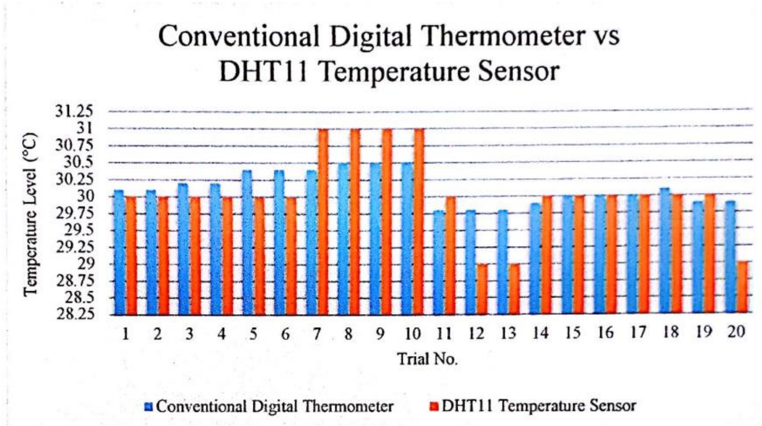
DATA GATHERED



SUMMARY			Alpha	0.01		Hyp Mean Diff	0	
Groups	*Count*	*Mean*	*Std Dev*	*Std Err*	*t*	*df*	*Cohen d*	*Effect r*
Conventional Digital Thermometer	20	30.125	0.248945					
DHT11 Temperature Sensor	20	30.05	0.604805					
Difference	20	0.075	0.433923	0.097028	0.772971	19	0.172842	0.174608

T TEST

	p-value	*t-crit*	*lower*	*upper*	*sig*
One Tail	0.224525	2.539483			no
Two Tail	0.449049	2.860935	-0.20259	0.352591	no

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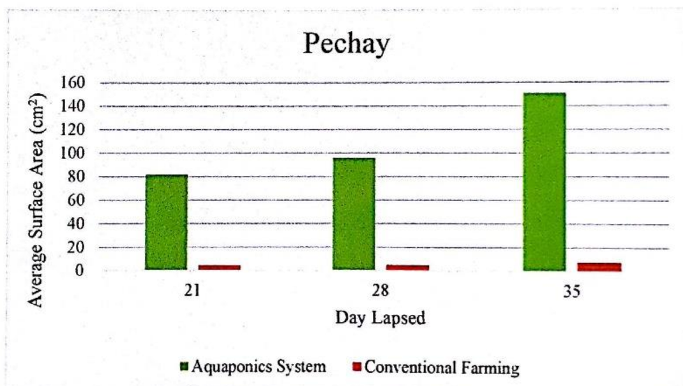
DATA GATHERED

Pechay		
Day Lapsed	Surface Area (cm^2)	
	Aquaponics System	Conventional Farming
21	81.64	4.49
28	95.75	4.85
35	150.61	7.49



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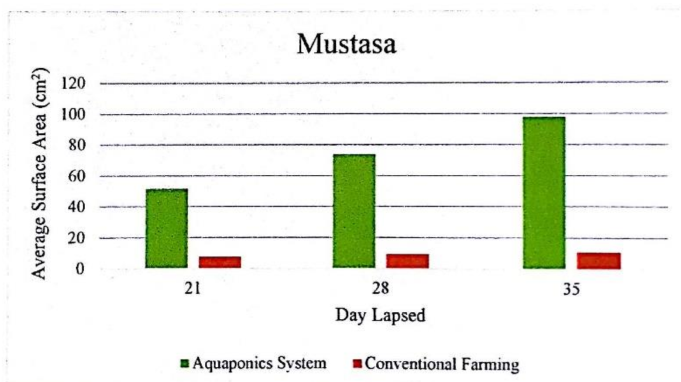
DATA GATHERED

Mustasa		
Day Lapsed	Surface Area (cm^2)	
	Aquaponics System	Conventional Farming
21	51.45	7.6
28	73.71	9.18
35	97.86	10.79



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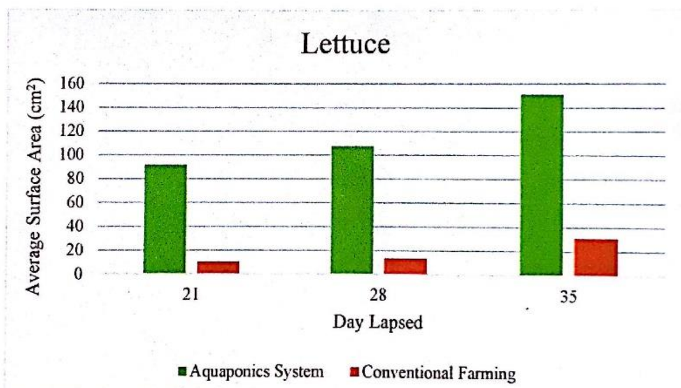
DATA GATHERED

Lettuce		
Day Lapsed	Surface Area (cm^2)	
	Aquaponics System	Conventional Farming
21	91.70	10.27
28	107.52	13.61
35	151.20	30.94



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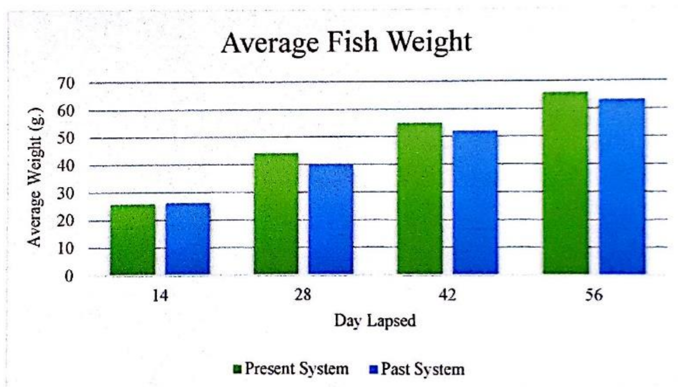
DATA GATHERED

Day Lapsed	Average Weight (g.)	
	Present System	Past System
14	25.8	26.2
28	45.25	40.1
42	54.9	52.1
56	65.85	63.11



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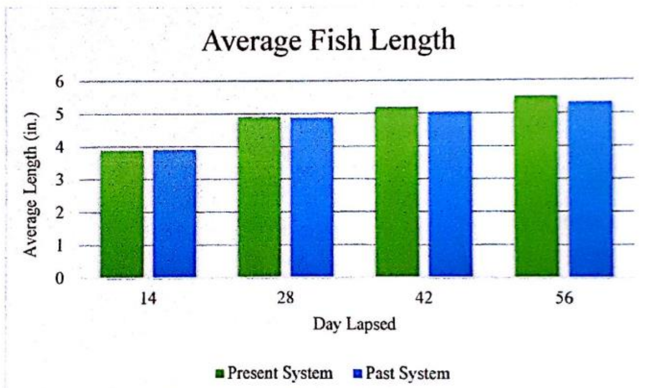
DATA GATHERED

Day Lapsed	Average Length (in.)	
	Present System	Past System
14	3.87	3.91
28	4.9	4.87
42	5.19	5.04
56	5.51	5.32



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EVALUATION FORM

Directions: Rate the following by placing a cross (x) mark on the box provided.

1 – Poor 2 – Fair 3 – Satisfactory 4 – Very Satisfactory 5 – Excellent

I. General Impact

	1	2	3	4	5
1. Novelty of the Project			X		
2. Industrial applicability			X		
3. Social Impact			X		

II. System

Functionality	1	2	3	4	5
1. Suitability			X		
2. Security				X	
3. Accuracy			X		
4. Functionality Compliance				X	
Usability					
1. Understandability				X	
2. Operability				X	
3. Attractiveness			X		
4. Usability Compliance			X		
Graphical User Interface					
1. User			X		
2. Informative			X		
3. Aesthetics			X		

Remarks:

Evaluated by:

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Directions: Rate the following by placing a cross (x) mark on the box provided.

1 – Poor   2 – Fair   3 – Satisfactory   4 – Very Satisfactory   5 – Excellent

I. General Impact

	1	2	3	4	5
1. Novelty of the Project			X		
2. Industrial applicability			X		
3. Social Impact				X	

II. System

Functionality	1	2	3	4	5
1. Suitability			X		
2. Security			X		
3. Accuracy			X		
4. Functionality Compliance			X		
Usability					
1. Understandability			X		
2. Operability				X	
3. Attractiveness				X	
4. Usability Compliance			X		
Graphical User Interface					
1. User				X	
2. Informative				X	
3. Aesthetics				X	

Remarks:

Econtanas
Emelito Contanas
Evaluated by:

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EVALUATION FORM

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1 – Poor 2 – Fair 3 – Satisfactory 4 – Very Satisfactory 5 – Excellent

I. General Impact

	1	2	3	4	5
1. Novelty of the Project				X	
2. Industrial applicability				X	
3. Social Impact				X	

II. System

Functionality	1	2	3	4	5
1. Suitability				X	
2. Security				X	
3. Accuracy			X		
4. Functionality Compliance			X		
Usability					
1. Understandability			X		
2. Operability			X		
3. Attractiveness				X	
4. Usability Compliance			X		
Graphical User Interface					
1. User			X		
2. Informative			X		
3. Aesthetics			X		

Remarks:

Evaluated by: 2/6/2018
LENY P. MORALES

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EVALUATION FORM

Directions: Rate the following by placing a cross (x) mark on the box provided.

1 – Poor 2 – Fair 3 – Satisfactory 4 – Very Satisfactory 5 – Excellent

I. General Impact

	1	2	3	4	5
1. Novelty of the Project			x		
2. Industrial applicability			x		
3. Social Impact				x	

II. System

Functionality	1	2	3	4	5
1. Suitability				x	
2. Security				x	
3. Accuracy			x		
4. Functionality Compliance			x		
Usability					
1. Understandability			x		
2. Operability			x		
3. Attractiveness					x
4. Usability Compliance			x		
Graphical User Interface					
1. User					x
2. Informative					x
3. Aesthetics				x	

Remarks:

Evaluated by:

Helen Magdaraog

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EVALUATION FORM

Directions: Rate the following by placing a cross (x) mark on the box provided.

1 – Poor 2 – Fair 3 – Satisfactory 4 – Very Satisfactory 5 – Excellent

I. General Impact

	1	2	3	4	5
1. Novelty of the Project				X	
2. Industrial applicability				X	
3. Social Impact				X	

II. System

Functionality	1	2	3	4	5
1. Suitability				X	
2. Security					X
3. Accuracy				X	
4. Functionality Compliance					X
Usability					
1. Understandability					X
2. Operability					X
3. Attractiveness					X
4. Usability Compliance				X	
Graphical User Interface					
1. User					X
2. Informative					X
3. Aesthetics					X

Remarks:
Good Job!!!

Evaluated by:
Ronnie C. Tangpuz Jr.

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EVALUATION FORM

Directions: Rate the following by placing a cross (x) mark on the box provided.

1 – Poor 2 – Fair 3 – Satisfactory 4 – Very Satisfactory 5 – Excellent

I. General Impact

	1	2	3	4	5
1. Novelty of the Project				x	
2. Industrial applicability				x	
3. Social Impact			x		

II. System

Functionality	1	2	3	4	5
1. Suitability				x	
2. Security				x	
3. Accuracy				x	
4. Functionality Compliance				x	
Usability					
1. Understandability				x	
2. Operability				x	
3. Attractiveness				x	
4. Usability Compliance				x	
Graphical User Interface					
1. User				x	
2. Informative				x	
3. Aesthetics				x	

Remarks:

Very adaptable system especialy for the future production, as one of new system in providing our food, and income generation, to be more effective in securing our supplies of vegetable in the coming days to come... but. but.. theres a needs to improve it more. for Productivity of Product...
Congratulation...to all your team.
God Bless you more...

Evaluated by:

Ate Joe Guefa
[signature]

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EVALUATION FORM

Directions: Rate the following by placing a cross (x) mark on the box provided.

1 – Poor   2 – Fair   3 – Satisfactory   4 – Very Satisfactory   5 – Excellent

I. General Impact

	1	2	3	4	5
1. Novelty of the Project				X	
2. Industrial applicability				X	
3. Social Impact				X	

II. System

Functionality	1	2	3	4	5
1. Suitability				X	
2. Security				X	
3. Accuracy				X	
4. Functionality Compliance				X	
Usability					
1. Understandability				X	
2. Operability				X	
3 Attractiveness				X	
4. Usability Compliance				X	
Graphical User Interface					
1. User				X	
2. Informative				X	
3. Aesthetics				X	

Remarks:

____

Evaluated by:

JOHN R. NADUA

APPENDIX B

Data of Past Study

Technological University of the Philippines
College of Engineering
Electronics Engineering Department

DATA GATHERED

December 9, 2016

Fish No.	ISFET		Glass Electrode		Unmonitored	
	Length (in)	Weight (g)	Length (in)	Weight (g)	Length (in)	Weight (g)
1	3.8	18	3.7	18	3.7	18
2	3.8	26	3.7	20	3.7	23
3	3.8	18	3.7	18	3.7	18
4	3.8	22	3.8	27	3.7	18
5	3.9	27	3.8	26	3.8	26
6	3.9	28	3.8	26	3.8	27
7	4.0	27	3.9	27	3.8	28
8	4.0	32	3.9	28	3.8	26
9	4.0	32	4.0	32	3.9	27
10	4.1	32	4.0	28	3.9	30
Average:	3.91	26.2	3.83	25.2	3.78	22.3

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ENGR. LEAN KARLO S. TOLENTINO
Panel Member / Adviser

Technological University of the Philippines
College of Engineering
Electronics Engineering Department

DATA GATHERED

December 23, 2016

Fish No.	ISFET		Glass Electrode		Unmonitored	
	Length (in)	Weight (g)	Length (in)	Weight (g)	Length (in)	Weight (g)
1	4.5	34	4.5	36	4.5	32
2	4.6	35	4.6	34	4.5	33
3	4.8	39	4.7	35	4.6	32
4	4.9	40	4.7	38	4.6	38
5	4.9	39	4.8	40	4.7	37
6	5.0	42	4.9	38	4.8	38
7	5.0	41	4.9	42	4.9	37
8	5.0	44	4.9	43	4.9	38
9	5.0	42	5.0	42	5.0	39
10	5.0	45	5.0	43	x	x
Average:	4.87	40.1	4.8	39.1	4.72	36

RENE T. MAGDARAOG
Eco Modular Specialist

ENGR. ROLANDO A. LONDONIO
City Cooperative Development Officer

ENGR. LEAN KARLO S. TOLENTINO
Panel Member / Adviser

Technological University of the Philippines
College of Engineering
Electronics Engineering Department

DATA GATHERED

January 6, 2017

Fish No.	ISFET		Glass Electrode		Unmonitored	
	Length (in)	Weight (g)	Length (in)	Weight (g)	Length (in)	Weight (g)
1	4.8	47	4.7	44	4.6	41
2	4.9	46	4.8	47	4.7	42
3	5.0	50	4.9	45	4.7	41
4	5.0	52	4.9	49	4.8	47
5	5.0	53	5.0	53	4.9	47
6	5.1	52	5.0	48	5.0	48
7	5.1	54	5.0	49	5.0	47
8	5.1	56	5.0	53	5.1	52
9	5.2	54	5.1	52	x	x
10	5.2	57	5.2	55	x	x
Average:	5.04	52.1	4.96	49.5	4.85	45.63

RENE T. MAGDARAOG
Eco Modular Specialist

ENGR. ROLANDO A. LONDONIO
City Cooperative Development Officer

ENGR. LEAN KARLO S. TOLENTINO
Panel Member / Adviser

Technological University of the Philippines
College of Engineering
Electronics Engineering Department

DATA GATHERED

January 22, 2017

Fish No.	ISFET		Glass Electrode		Unmonitored	
	Length (in)	Weight (g)	Length (in)	Weight (g)	Length (in)	Weight (g)
1	5	57	4.8	55	4.8	52
2	5.1	61	4.9	60	4.8	52
3	5.2	59	5.0	59	4.8	57
4	5.3	63	5.1	63	4.9	52
5	5.4	65	5.1	62	5.1	57
6	5.4	64	5.2	65	5.2	59
7	5.5	68	5.4	63	5.3	63
8	5.5	65	5.4	65	x	x
9	5.5	66	5.5	66	x	x
10	x	x	x	x	x	x
Average:	5.32	63.11	5.15	60.67	4.98	56

RENE T. MAGDARAOG
Eco Modular Specialist

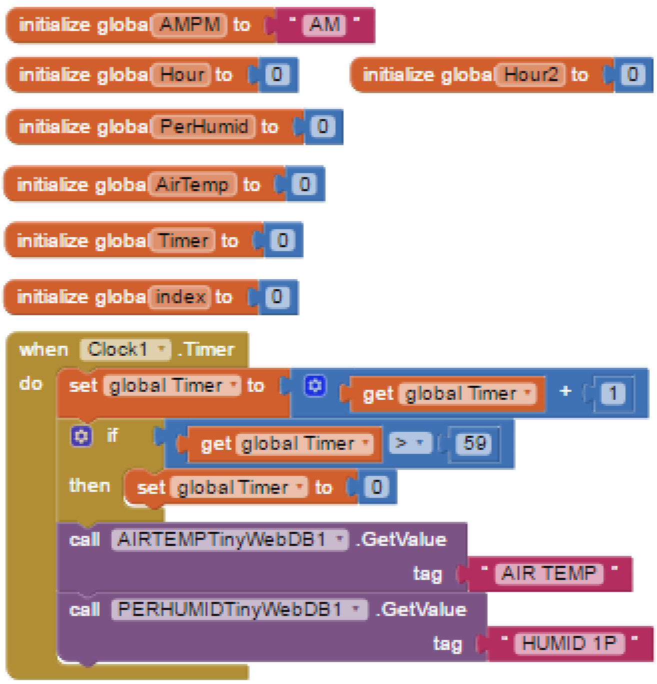
ENGR. ROLANDO A. LONDONIO
City Cooperative Development Officer

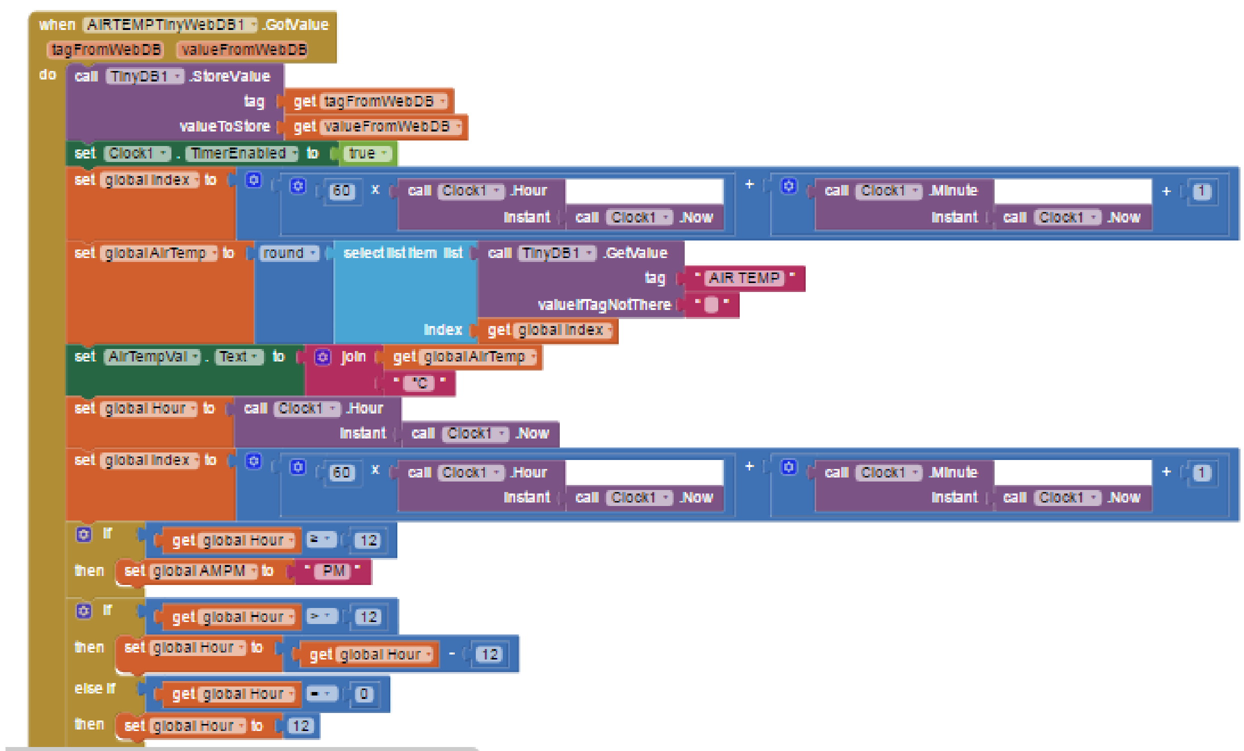
ENGR. LEAN KARLO S. TOLENTINO
Panel Member / Adviser

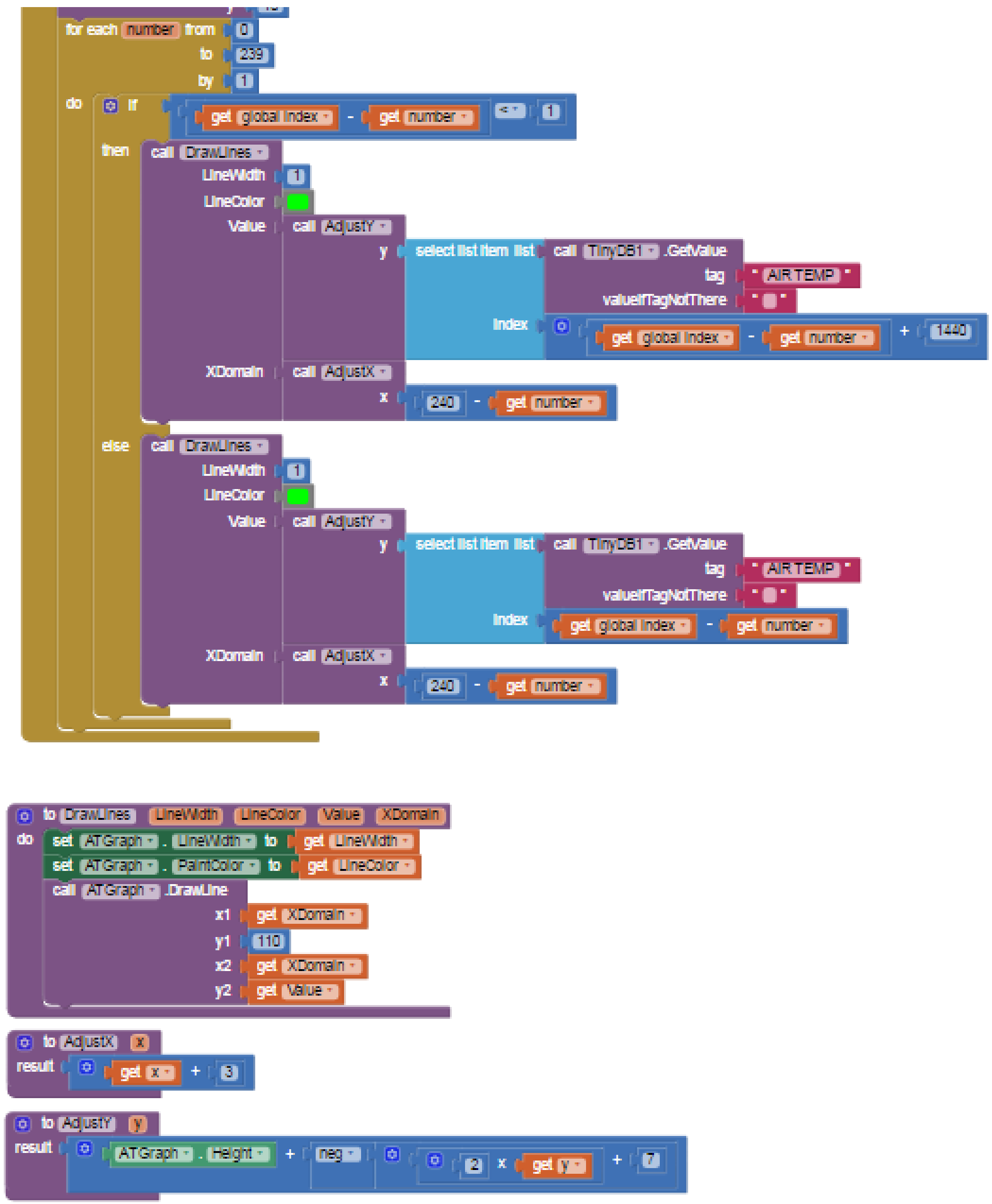
APPENDIX C

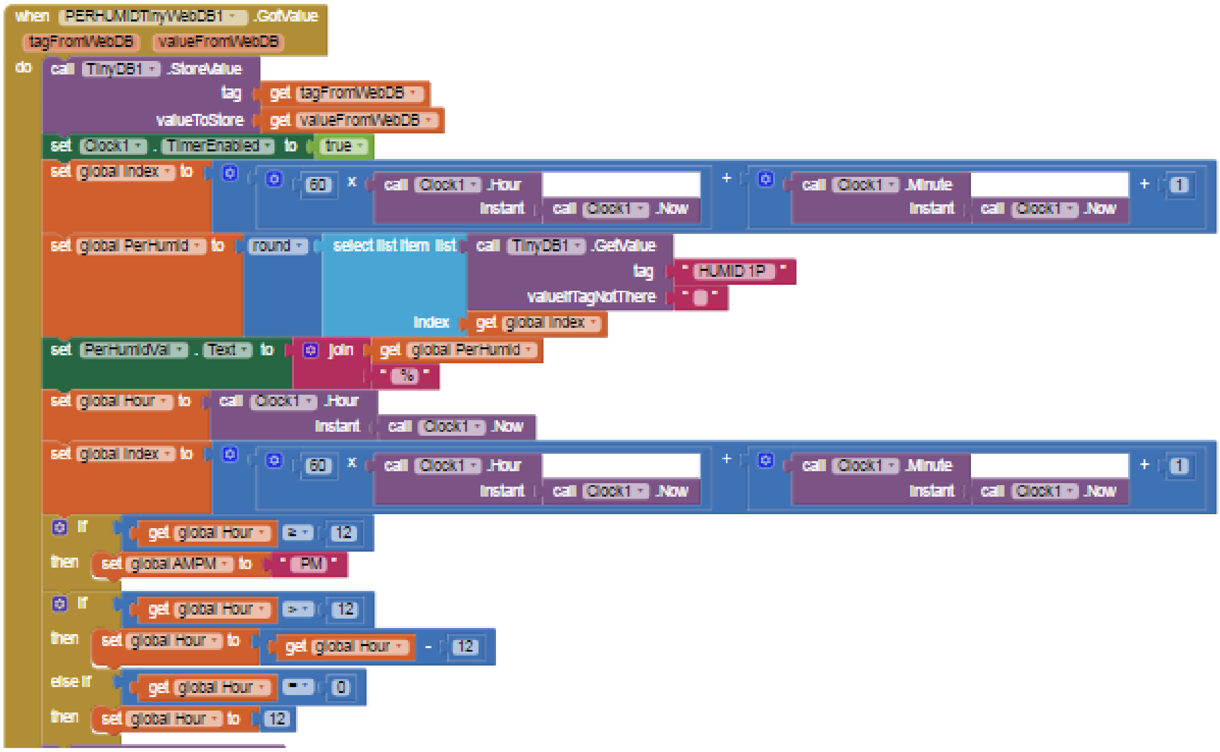
Source Codes

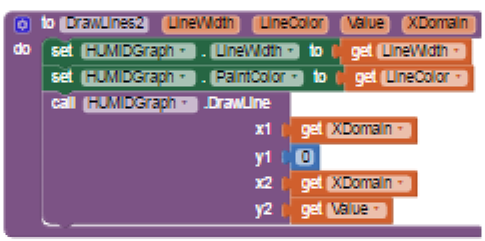
<u>**Mit App Inventor**</u>



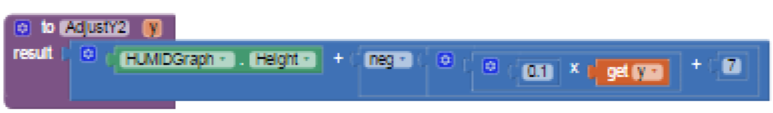


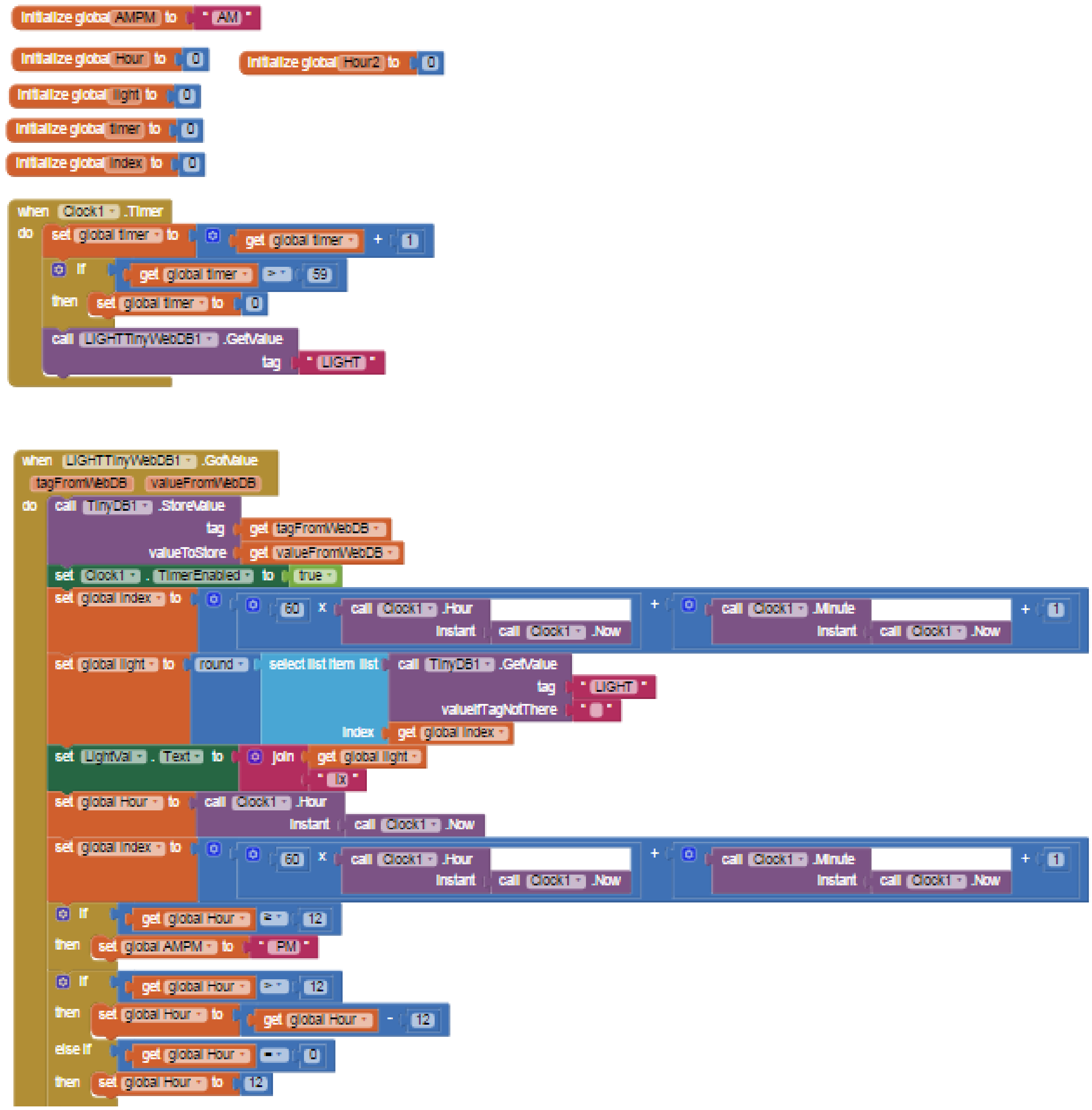

for each number from 0
to 239
by 1
do
if get global index - get number < 1
then call DrawLines
LineWidth 1
LineColor
Value call AdjustY
y select list item list call TinyDB1 .GetValue
tag " AIR TEMP "
valueIfTagNotThere " "
index get global index - get number + 1440
XDomain call AdjustX
x 240 - get number
else call DrawLines
LineWidth 1
LineColor
Value call AdjustY
y select list item list call TinyDB1 .GetValue
tag " AIR TEMP "
valueIfTagNotThere " "
index get global index - get number
XDomain call AdjustX
x 240 - get number
to DrawLines LineWidth LineColor Value XDomain
do set ATGraph . LineWidth to get LineWidth
set ATGraph . PaintColor to get LineColor
call ATGraph .DrawLine
x1 get XDomain
y1 110
x2 get XDomain
y2 get Value
to AdjustX x
result get x + 3
to AdjustY y
result ATGraph . Height + neg 2 x get y + 7


when PERHUMIDTinyWebDB1 .GotValue
tagFromWebDB valueFromWebDB
do call TinyDB1 .StoreValue
tag get tagFromWebDB
valueToStore get valueFromWebDB
set Clock1 . TimerEnabled to true
set global Index to 60 x call Clock1 .Hour instant call Clock1 .Now + call Clock1 .Minute instant call Clock1 .Now + 1
set global PerHumid to round select list item list call TinyDB1 .GetValue
tag " HUMID 1P "
valueIfTagNotThere " "
index get global Index
set PerHumidVal . Text to join get global PerHumid " % "
set global Hour to call Clock1 .Hour instant call Clock1 .Now
set global Index to 60 x call Clock1 .Hour instant call Clock1 .Now + call Clock1 .Minute instant call Clock1 .Now + 1
if get global Hour ≥ 12
then set global AMPM to " PM "
if get global Hour > 12
then set global Hour to get global Hour - 12
else if get global Hour = 0
then set global Hour to 12

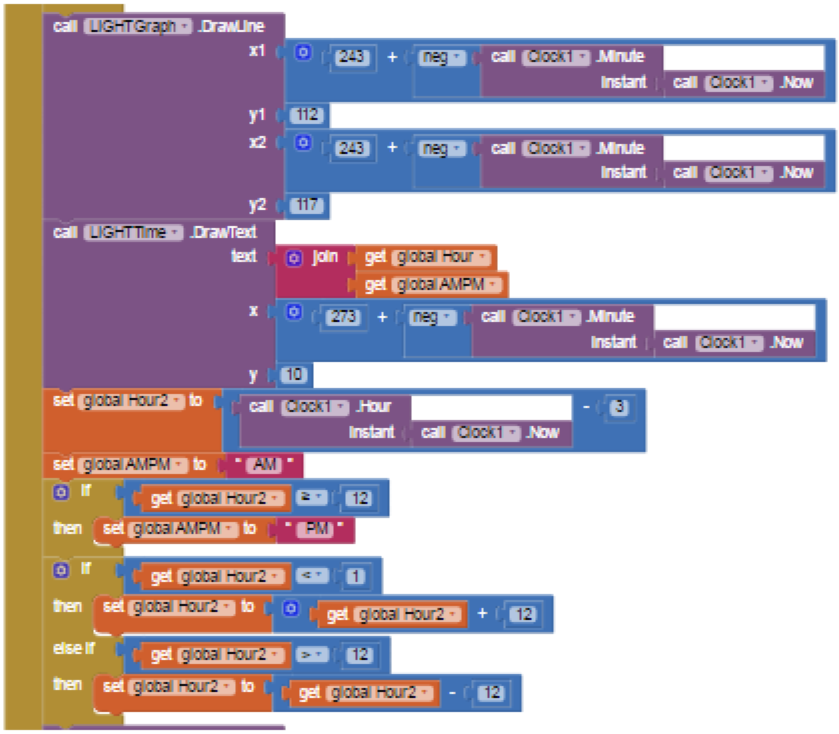

to DrawLines2 LineWidth LineColor Value XDomain
do set HUMIDGraph . LineWidth to get LineWidth
set HUMIDGraph . PaintColor to get LineColor
call HUMIDGraph .DrawLine
x1 get XDomain
y1 0
x2 get XDomain
y2 get Value


to AdjustX2 x
result get x + 3

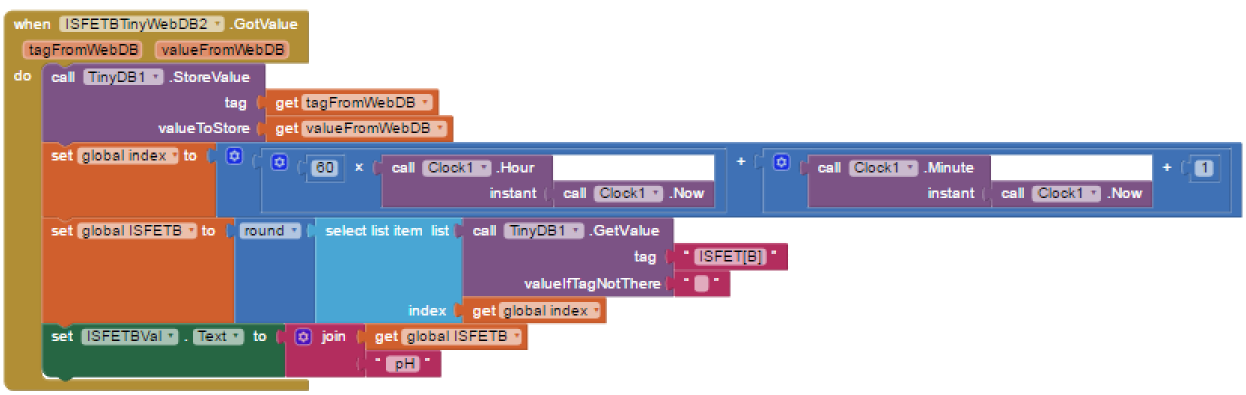

to AdjustY2 y
result HUMIDGraph . Height + neg 0.1 x get y + 7



initialize global AMPM to "AM"
initialize global Hour to 0
initialize global Hour2 to 0
initialize global light to 0
initialize global timer to 0
initialize global index to 0
when Clock1 .Timer
do set global timer to get global timer + 1
if get global timer ≥ 59
then set global timer to 0
call LIGHTTinyWebDB1 .GetValue
tag "LIGHT"
when LIGHTTinyWebDB1 .GotValue
tagFromWebDB valueFromWebDB
do call TinyDB1 .StoreValue
tag get tagFromWebDB
valueToStore get valueFromWebDB
set Clock1 . TimerEnabled to true
set global index to 60 x call Clock1 .Hour instant call Clock1 .Now + call Clock1 .Minute instant call Clock1 .Now + 1
set global light to round select list item list call TinyDB1 .GetValue
tag "LIGHT"
valueIfTagNotThere " "
index get global index
set LightVal . Text to join get global light
" lx "
set global Hour to call Clock1 .Hour
instant call Clock1 .Now
set global index to 60 x call Clock1 .Hour instant call Clock1 .Now + call Clock1 .Minute instant call Clock1 .Now + 1
if get global Hour ≥ 12
then set global AMPM to "PM"
if get global Hour > 12
then set global Hour to get global Hour - 12
else if get global Hour = 0
then set global Hour to 12



call LIGHTGraph .DrawLine
x1 243 + neg call Clock1 .Minute instant call Clock1 .Now
y1 112
x2 243 + neg call Clock1 .Minute instant call Clock1 .Now
y2 117
call LIGHTTime .DrawText
text join get global Hour get global AMPM
x 273 + neg call Clock1 .Minute instant call Clock1 .Now
y 10
set global Hour2 to call Clock1 .Hour instant call Clock1 .Now - 3
set global AMPM to " AM "
if get global Hour2 ≥ 12
then set global AMPM to " PM "
if get global Hour2 < 1
then set global Hour2 to get global Hour2 + 12
else if get global Hour2 > 12
then set global Hour2 to get global Hour2 - 12



when ISFETBTinyWebDB2 .GotValue
tagFromWebDB valueFromWebDB
do call TinyDB1 .StoreValue
tag get tagFromWebDB
valueToStore get valueFromWebDB
set global index to 60 × call Clock1 .Hour instant call Clock1 .Now + call Clock1 .Minute instant call Clock1 .Now + 1
set global ISFETB to round select list item list call TinyDB1 .GetValue
tag " ISFET[B] "
valueIfTagNotThere " "
index get global index
set ISFETBVal . Text to join get global ISFETB " pH "

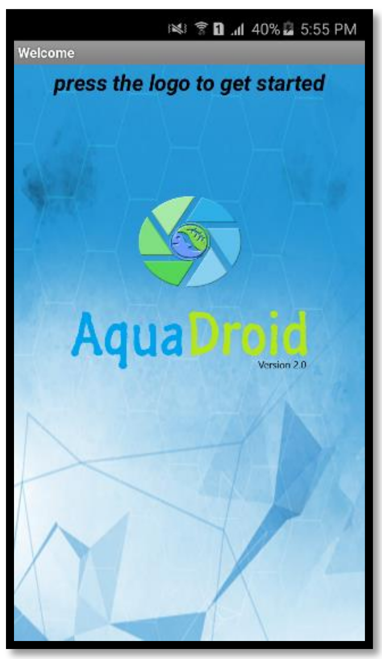
APPENDIX D

AquaDroid V2.0 User Guide

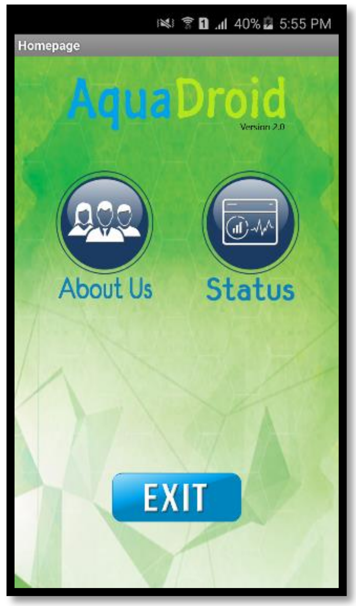
HOW TO USE

AquaDroid
Version 2.0

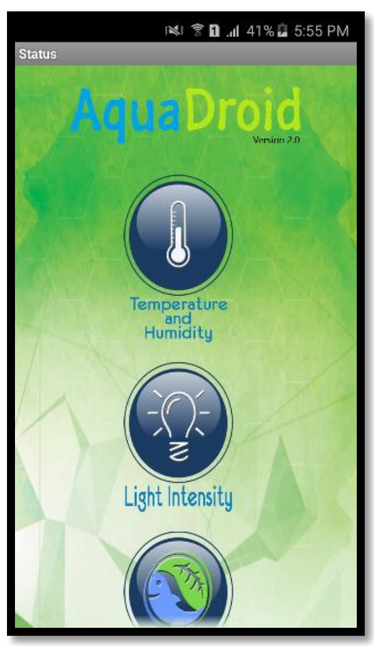
1. Enable WIFI on the smartphone. Press the logo to start the application.



2. Press the Status to proceed in viewing real time readings. Press the About Us to proceed in viewing the title of the project and the authors.



3. In the Status Page, choose which parameter reading the user wants to monitor in real-time. Enable WIFI on the smartphone. Press the logo to start the application.



APPENDIX E

Project Documentation

First Meeting with Pasay City Cooperative Officials and

the Previous Aquaponics Proponents

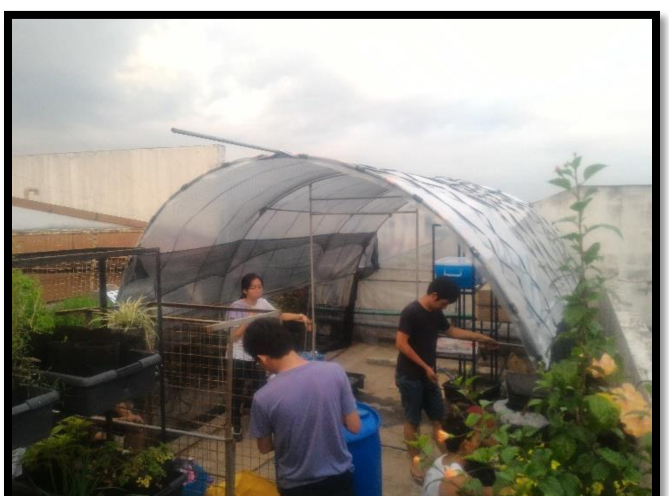
March 6, 2017

Meeting and Consultation with Pasay City Cooperative Official

June 12, 2017

Assembling the Greenhouse

(Pasay City Market Rooftop)



Making the Smart Aquaponics

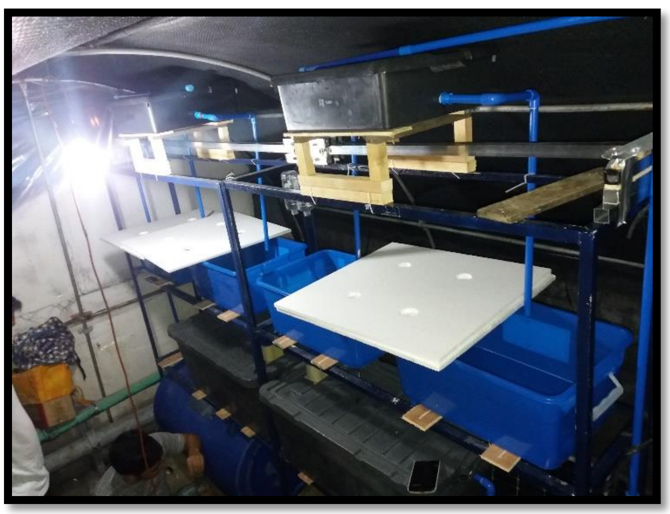
(Pasay City Market Rooftop)

Making the Smart Aquaponics

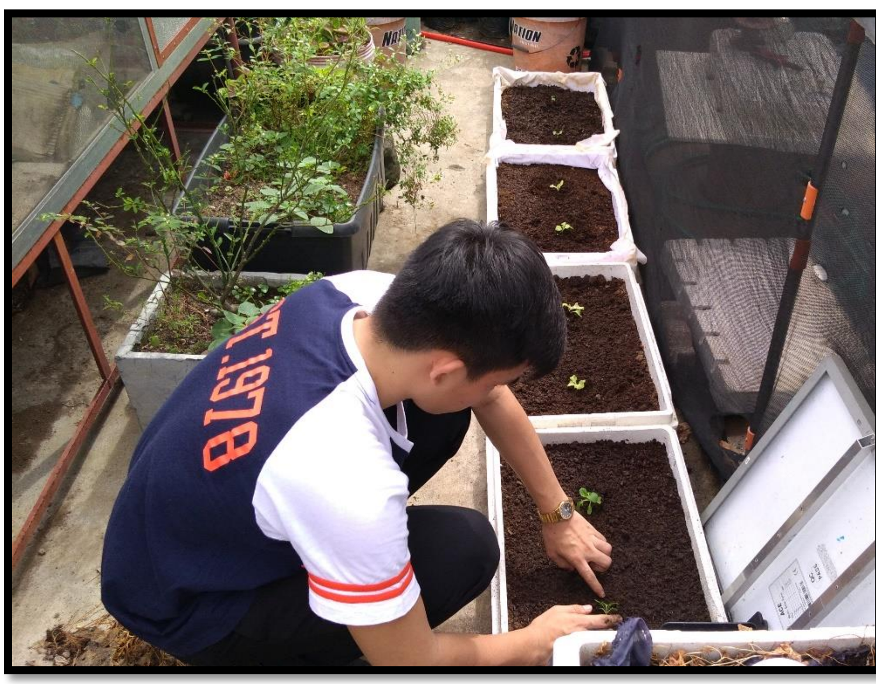
(Pasay City Market Rooftop)

Making the Smart Aquaponics

(Pasay City Market Rooftop)



Transplanting



Data Gathering

Evaluation with Pasay City Cooperative

Defenses

APPENDIX F

Proponent's Profile Layout

SHAYNE NATHALIE DIMAIWAT AMORA
B64 L91 PH1C San Lorenzo South Subdivision,
Santa Rosa City, Laguna
+639262510648
shaynenathalieamora17@gmail.com

EDUCATION

Tertiary	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES - MANILA Ayala Boulevard, Ermita, Manila Bachelor of Science in Electronics Engineering DOST Scholar – R.A. 7687 2013 - present
Secondary	SANTA ROSA SCIENCE AND TECHNOLOGY HIGH SCHOOL JP Rizal Street, Santa Rosa City, Laguna 2009 – 2013
Primary	EMMANUEL CHRISTIAN SCHOOL Phase 1-E San Lorenzo South, Santa Rosa City 2004 – 2009
	DOMINICAN COLLEGE OF STA. ROSA Balibago, Santa Rosa City, Laguna 2001 – 2004

CO-CURRICULAR ACTIVITIES

2013 – present	Member, TUP – DOST SCHOLAR'S CLUB
2013 – present	Member, Organization of Electronics Engineering Students, Technological University of the Philippines – Manila
2016 – 2017	Secretary, Organization of Electronics Engineering Students, Technological University of the Philippines – Manila
2015 – present	Member, Institute of Electronics Engineers of the Philippines – Manila Student Chapter
2017 – present	Board of Director, Institute of Electronics Engineers of the Philippines – Manila Student Chapter
28 January 2018	Participated in UP Engineering Innovations Congress 2018 – Expo held at University of the Philippines – Diliman, Quezon City

SEMINARS ATTENDED

21 November 2017	TECHNO TALK ON SYNERGY: ELECTRICAL AND ELECTRONICS ENGINEERING SUMMIT 2017 Held at Institute of Biology Auditorium University of the Philippines – Diliman, Quezon City
22 January 2018	INTRODUCTION TO DATA SCIENCE Held at Vista Verde Resort Function Hall Angeles, Pampanga Speaker: Engr. Timothy M. Amado
27 January 2018	UP ENGINEERING INNOVATIONS CONGRESS 2018: SOCIAL ENTREPRENEURIAL ENGINEERING SYMPOSIUM Held at College of Engineering Theater University of the Philippines – Diliman, Quezon City
3 February 2018	INTRODUCTION TO FUSION 360 Held at De La Salle – Santiago Zobel School
10 February 2018	NON-TECHNICAL SESSION ON LETRAN MANILA ENGINEERING SYMPOSIUM 2018 Held at Colegio de San Juan de Letran
10 February 2018	TECHNICAL SESSION ON LETRAN MANILA ENGINEERING SYMPOSIUM 2018 Held at Colegio de San Juan de Letran

PERSONAL BACKGROUND

Date of birth: December 17, 1996

Place of birth:

Age: 20 years old

Gender: Female

DANIEL KRISTOPHER TENORIO BARTOLATA
Door 5, Cmpnd 14, Dagot St.,
Brgy. Manresa, Q.C.
+639959208019
danielkristopherb@gmail.com

EDUCATION

Tertiary TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES – MANILA
Ayala Boulevard, Ermita, Manila
Bachelor of Science in Electronics Engineering
DOST Scholar – R.A. 7687
Rotary Club of Balintawak Scholar
2013 - present

Secondary BALINGASA HISH SCHOOL
J Aquino Cruz St., Balingasa, Q.C.
7th Honorable Mention
2011 – 2013

THE SISTERS OF MARY SCHOOL
Adlas, Silang, Cavite
2009 – 2011

Primary DEWEY ELEMENTARY SCHOOL
Brgy. Dewey, Bolinao, Pangasinan
2nd Honorable Mention
2004 – 2009

CO-CURRICULAR ACTIVITIES

2013 – present Member, Organization of Electronics Engineering Students, Technological University of the Philippines – Manila

2013 – present Member, TUP – DOST Scholars Club

2015 – present Member, Institute of Electronics Engineers of the Philippines – Manila Student Chapter

28 January 2018 Participated in UP Engineering Innovations Congress 2018 – Expo held at University of the Philippines – Diliman, Quezon City

SEMINARS ATTENDED

21 November 2017	TECHNO TALK ON SYNERGY: ELECTRICAL AND ELECTRONICS ENGINEERING SUMMIT 2017 Held at Institute of Biology Auditorium University of the Philippines – Diliman, Quezon City
22 January 2018	INTRODUCTION TO DATA SCIENCE Held at Vista Verde Resort Function Hall Angeles, Pampanga Speaker: Engr. Timothy M. Amado
27 January 2018	UP ENGINEERING INNOVATIONS CONGRESS 2018: SOCIAL ENTREPRENEURIAL ENGINEERING SYMPOSIUM Held at College of Engineering Theater University of the Philippines – Diliman, Quezon City
3 February 2018	INTRODUCTION TO FUSION 360 Held at De La Salle – Santiago Zobel School

PERSONAL BACKGROUND

Date of birth: December 10, 1996
Place of birth: Manila City
Age: 20 years old
Gender: Male
Height: 5’5”
Weight: 60 kgs.
Civil Status: Single
Religion: Roman Catholic
Father’s Name:
Mother’s Name: Jeralyn T. Bartolata

JUNE CARLO LOPEZ SOBREPEÑA
No. 7-D Syquio St. Zone 7
Central Signal, Taguig City
+639269360372
junecarlosobrepena@gmail.com

EDUCATION

Tertiary	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES – MANILA Ayala Boulevard, Ermita, Manila Bachelor of Science in Electronics Engineering Taguig L.A.N.I. Scholar 2013 - present
Secondary	INTEGRATED MONTESSORI CENTER No. 51 Diego Silang St., AFPOVAI, Ph 2, Fort Bonifacio, Taguig City Merit Awardee 2009 – 2013
Primary	INTEGRATED MONTESSORI CENTER No. 51 Diego Silang St., AFPOVAI, Ph 2, Fort Bonifacio, Taguig City 1st Honorable Mention 2003 – 2009

CO-CURRICULAR ACTIVITIES

2013 – present	Member, Organization of Electronics Engineering Students, Technological University of the Philippines – Manila
2015 – present	Member, Institute of Electronics Engineers of the Philippines – Manila Student Chapter
28 January 2018	Participated in UP Engineering Innovations Congress 2018 – Expo held at University of the Philippines – Diliman, Quezon City

SEMINARS ATTENDED

21 November 2017	TECHNO TALK ON SYNERGY: ELECTRICAL AND ELECTRONICS ENGINEERING SUMMIT 2017 Held at Institute of Biology Auditorium University of the Philippines – Diliman, Quezon City

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27 January 2018	UP ENGINEERING INNOVATIONS CONGRESS 2018: SOCIAL ENTREPRENEURIAL ENGINEERING SYMPOSIUM Held at College of Engineering Theater University of the Philippines – Diliman, Quezon City
3 February 2018	INTRODUCTION TO FUSION 360 Held at De La Salle – Santiago Zobel School

PERSONAL BACKGROUND

Date of birth: November 1, 1995

Place of birth: Manila City

Age: 22 years old

Gender: Male

Height: 5’4”

Weight: 52 kgs.

Civil Status: Single

Religion: Roman Catholic

Father’s Name:

Mother’s Name:

JOSHUA RICART VALDERAMA SARUCAM
215 Kaypian, San Jose Del Monte, Bulacan
+639272299139
jrsarucam1224@gmail.com

EDUCATION

Tertiary	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES – MANILA Ayala Boulevard, Ermita, Manila Bachelor of Science in Electronics Engineering DOST Scholar – R.A. 7687 2013 - present
Secondary	BULACAN STANDARD ACADEMY Poblacion, San Jose Del Monte, Bulacan 2009 – 2013
Primary	PERPETUAL HELP ACADEMY Kaypian, San Jose Del Monte, Bulacan 2003 – 2009

CO-CURRICULAR ACTIVITIES

2013 – present	Member, Organization of Electronics Engineering Students, Technological University of the Philippines – Manila
2013 – present	Member, TUP – DOST Scholars Club
2015 – present	Member, Institute of Electronics Engineers of the Philippines – Manila Student Chapter
28 January 2018	Participated in UP Engineering Innovations Congress 2018 – Expo held at University of the Philippines – Diliman, Quezon City

SEMINARS ATTENDED

21 November 2017	TECHNO TALK ON SYNERGY: ELECTRICAL AND ELECTRONICS ENGINEERING SUMMIT 2017 Held at Institute of Biology Auditorium University of the Philippines – Diliman, Quezon City
22 January 2018	INTRODUCTION TO DATA SCIENCE Held at Vista Verde Resort Function Hall Angeles, Pampanga Speaker: Engr. Timothy M. Amado

27 January 2018	UP ENGINEERING INNOVATIONS CONGRESS 2018: SOCIAL ENTREPRENEURIAL ENGINEERING SYMPOSIUM Held at College of Engineering Theater University of the Philippines – Diliman, Quezon City
3 February 2018	INTRODUCTION TO FUSION 360 Held at De La Salle – Santiago Zobel School

PERSONAL BACKGROUND

Date of birth: December 24, 1996
Place of birth: Poblacion, San Jose Del Monte, Bulacan
Age: 21 years old
Gender: Male
Height: 5’5”
Weight: 45 kgs.
Civil Status: Single
Religion: Roman Catholic
Father’s Name: Ricarte L. Sarucam
Mother’s Name: Melody V. Sarucam

KRISTINE YVONNE POLISTICO SOMBOL
B6 L41 PH2B Citihomes Subd., Molino 4
Bacoor City, Cavite
+639176614882
kristineyvonnesombol@gmail.com

EDUCATION

Tertiary	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES – MANILA Ayala Boulevard, Ermita, Manila Bachelor of Science in Electronics Engineering 2013 - present
Secondary	MANILA SCIENCE HIGH SCHOOL Taft Ave. cor. Padre Faura St., Ermita, Manila 2009 – 2013
Primary	HARRELL HORNE INTEGRATED SCHOOL #3 Basa St., Bahayang Pag-asa Subd., Molino 5, Bacoor City, Cavite Silver Medalist 2003 – 2009

CO-CURRICULAR ACTIVITIES

27 February 2010	Participated in an outreach activity held at Asilo de San Vicente de Paul
2012 – 2013	Member, Robotics Club, Manila Science High School
2011 – 2013	Member, Lifebox - MaSci, Manila Science High School
2013 – present	Member, Organization of Electronics Engineering Students, Technological University of the Philippines – Manila
2015 – present	Member, Institute of Electronics Engineers of the Philippines – Manila Student Chapter
2-3 December 2017	Participated in Unionbank Hackathon (UHack) held at International Trade Center, Sen. Gil Puyat Ave., Pasay City
28 January 2018	Participated in UP Engineering Innovations Congress 2018 – Expo held at University of the Philippines – Diliman, Quezon City

SEMINARS ATTENDED

21 November 2017	TECHNO TALK ON SYNERGY: ELECTRICAL AND ELECTRONICS ENGINEERING SUMMIT 2017 Held at Institute of Biology Auditorium University of the Philippines – Diliman, Quezon City
22 January 2018	INTRODUCTION TO DATA SCIENCE Held at Vista Verde Resort Function Hall Angeles, Pampanga Speaker: Engr. Timothy M. Amado
27 January 2018	UP ENGINEERING INNOVATIONS CONGRESS 2018: SOCIAL ENTREPRENEURIAL ENGINEERING SYMPOSIUM Held at College of Engineering Theater University of the Philippines – Diliman, Quezon City
3 February 2018	INTRODUCTION TO FUSION 360 Held at De La Salle – Santiago Zobel School
10 February 2018	NON-TECHNICAL SESSION ON LETRAN MANILA ENGINEERING SYMPOSIUM 2018 Held at Colegio de San Juan de Letran
10 February 2018	TECHNICAL SESSION ON LETRAN MANILA ENGINEERING SYMPOSIUM 2018 Held at Colegio de San Juan de Letran

PERSONAL BACKGROUND

Date of birth: October 29, 1996
Place of birth: Pamplona, Las Piñas
Age: 21 years old
Gender: Female
Height: 5’2”
Weight: 50 kgs.
Civil Status: Single
Religion: Roman Catholic
Father’s Name: Rogelio T. Sombol
Mother’s Name: Liberty P. Sombol