Smart Plant Monitoring System Using Aquaponics Production Technological with Arduino Development Environment (IDE) and SMS Alert: A Prototype

https://doi.org/10.3991/ijim.v16i22.34581

Zahari Abu Bakar(✉), Muhammad Zairil Muhammad Nor, Kamaru Adzha Kadiran, Mohamad Farid Misnan, Maisarah Noorezam
Cawangan Johor Kampus Pasir Gudang, Universiti Teknologi MARA, Masai, Malaysia
zahar311@uitm.edu.my

Abstract—Aquaponics is one of the agricultural production technological advancements that should be publicized. Climate change, population expansion, water scarcity, soil degradation, and food security are just a few of the world's most pressing issues. Aquaponics, which is a closed-loop system that combines hydroponics and aquaculture, may be able to deal with issues like climate change, population expansion, water scarcity, soil degradation, and food security. Thus, this paper aims to design and construct an aquaponics system that combines fish farming with plant growth. The system used a variety of sensors, including temperature and humidity sensors, ultrasonic sensors, and pH sensors, as well as microcontrollers like Arduino, to monitor and manage the water quality, plant humidity, and other variables. When the sensor identifies any abnormal circumstance, early warnings in the form of SMS and push notifications are immediately given to the user to ensure a healthy growing environment for fish and plants. The Arduino Development Environment (IDE) software is used to write a programme that connects the microcontroller to various sensors and other devices. pH sensors, temperature and humidity sensors, ultrasonic sensors, liquid crystal displays (LCDs), and GSM circuits are all built and connected to the system. A GSM notification message is sent to a mobile phone when the pH, temperature, and ultrasonic sensor findings are out of range. The data from this system's monitoring reveals the values that have been taken on a daily basis. The graph demonstrated that the plant's growth is increasing every day.

Keywords—Aquaponics, Arduino, IDE, SMS, agriculture

1 Introduction

Agriculture remains a significant field of Malaysia's economy, accounting for 12% of national GDP and employing 16% of the workforce. Thus far, the three major crops which are rubber, palm oil, and cocoa have dominated agricultural exports, despite Malaysia's share of global production of these crops declining steadily over the last two decades. Malaysian farmers also grow a variety of fruits and vegetables for the domestic market, including bananas, coconuts, durian, pineapples, paddy, and rambutan. Since these crops are seasonal, farmers need to consider an alternative to maintain their business. Therefore, recirculating farms were introduced. Recirculating farms are land-based, closed-loop systems that use continuously cleaned water to collect fish and produce food. These farms will cultivate plants (hydroponics), fish (aquaculture), or both plants and fish at the same time (aquaponics) [1].

Aquaponics refers to a food processing technique that combines aquaculture and hydroponics (the cultivation of plants in water), in which nutrient-rich aquaculture water is fed to hydroponically grown plants, with nitrifying bacteria converting ammonia to nitrates [2]. Aquaponics holds great promise for a long-term organic crop production, aquaculture, and water use. Instead of being drained into the ocean, fish waste is recycled and used to cultivate plants. Water is recirculated in a closed structure, reducing resource demand.

In Malaysia, at Kundasang, Ranau, Sabah, a small group of young farmers is using aquaponics and hydroponics to cultivate vegetables. Since December 2019, they have been experimenting with aquaponics and hydroponics under the supervision of the Kinabalu Area Farmers Organisation (PPK). In Kuala Lumpur, the Urban Greenlife farm is run by Chin Kwe Fok and six other shareholders [3]. It runs on an aquaponic system where nutrient-rich water produced by tilapia is fed to the plants before being recirculated back into the fish tanks. The farm's success is a result of the mutual health between the plants and the aquatic animals. Chin and his co-directors hope to establish working relationships with nearby restaurants and supply fresh vegetables straight to their kitchens as consumers' awareness about organic produce improves.

Since aquaponics uses the same systems as hydroponics, there aren't many variations in how the system operates, apart from the addition of fish in the water tank(s). Drip irrigation, flood and drain, deep culture or water-submerged roots, and the nutrient film technique are both highly compatible and adaptable to blending with rising fish [11]. By using the latest technology, this system can be created automatically with a monitoring system. The monitoring system will measure temperature, humidity, pH level, and water level in one place without one-by-one monitoring. The system uses Arduino Mega with specified coding to make this system run automatically. It also uses a GSM module that will notify the user for monitoring and controlling the good quality of plants. Furthermore, with the systems described above, an aquaponics system does not need a constant monitoring. The consumer should control the pacing of the aquaponics cycle for maximum yield and balanced power consumption.

2 Literature review

There is a large volume of published studies describing smart plant monitoring systems. The current study recognizes the modest number of research studies that have built a smart plant monitoring system with SMS alerts. As a starting point for the project, these literature reviews were used as references.

The first study is "Smart Aquaponic with Monitoring and Control System Based on IoT" authored by Vernandhes, W. et.al (year) [4]. Smart Growbox was created specifically for this project to assist with the hardware design, which included sensors, relays, an Ethernet shield, and an Arduino. The amount of water vapor in the air was measured using DHT 22 sensors, which can affect the rate of transpiration and how nutrients are obtained. Light-emitting diodes (LEDs) were utilized to substitute the sunlight that is most effective in boosting plant growth. To calculate the output value of the amount of electricity, a soil moisture sensor was utilized to measure the moisture in the soil.

Next, “IoT Smart Agriculture for Aquaponics and Maintaining a Goat Stall System” by Mohammad Kamil Rostam Effendi, et.al (year) focuses on the fundamental idea of remotely controlling and monitoring animals and plants’ breeding and care. Wi-Fi module ESP8266, ESP-01, NODEMCU ESP8266 Wi-Fi, and Controller Board ESP-12 V2 were the components utilized in this project. A similar purpose of monitoring the aquaponic system was also designed by S A Z Murad, et al (year) [5] with the “Aquaponics Water Monitoring System using Arduino Microcontroller” project to specifically monitor and control the water parameters in the fish tank.

Another project developed was “Smart Aquaponics System for Urban Farming" by Thu, Y K and Keong, A N (2017) [6]. This project attempted to design and develop a system that can synergize fish farming and plant growing by gathering all the data from various sensors monitoring the sensor information and controlling the system accordingly. This system was developed by integrating seven modules which are a data acquisition unit that uses five sensors, an alarm unit that consists of a green LED, red LED, and a buzzer, a system rectification unit to activate or deactivate the actuators, a central processing unit that contains two sections which are Arduino Mega and Raspberry Pi, web application, mobile application, and cloud server. Another farming-related project is “Design & Implementation of Indoor Farming using Automated Aquaponics System” by M.N Mamatha and S.N. Namratha (2017) [7]. The system used Arduino Uno as a microcontroller and several sensors such as a pH sensor, temperature sensor, and LDR sensor.

The next reviewed project is “The Smart Aquaponics Greenhouse” by Pantazi, D. et al (2018) [8]. There are three different types of sensors used to monitor the system which include two DHT-11 sensors to keep an eye on the humidity and temperature of the air. These sensors send data every two seconds. To track the temperature of the water, this project used a resin-encapsulated metal SNS-TMP10 analogue sensor while the light sensor was used to monitor the lighting level in the environment. The water was pumped out of the fish tank to the greenhouse using nutrient enrichment.

"Automated Aquaponics Maintenance System" is another study describing smart plant monitoring sytem written by Muhammad Farhan Mohd Puad, et.al (2019) [9]. The Raspberry Pi 3's B+ Model B+ microprocessor was used as the automation core along with a microcontroller from the Arduino Nano. In this study, three analog sensors which are the water level sensor, pH sensor, and ambient light sensor were employed. However, there are limited topics covered in this study, which are light emission automation, LED lighting at night, and maintaining the water level in an aquaponic system. For general purposes, data from the Raspberry Pi is transferred from its GPIO ports to the Arduino digital ports. It is connected to the Internet using a portable Wi-Fi modem.

Prabha R, et.al (2020) [10] created an “IoT Managed Aquaponic System” to detect NH_3 gas by utilizing an ammonia sensor with a DC 5V operating voltage.The gas sensor picks up the scent of broken-down smoke, and proportionality may be used to determine how much degraded alkaline is present in the water. The characteristics of water have been determined using LM35 sensor ammonites and CO2 sensors. Another project is "Aquaponics Automated Water Quality Monitoring System" which focuses on how crucial water quality is to an aquaponic system. As the project owners, Abel Kurian Oommen, et.al (2019) [11] suggested the most recent color sensor, the TCS3200, along with an enhanced optical system and an STM32 microprocessor were used to develop the system.

Last but not least, the "IoT Based Automatic Monitoring System for Water Nutrition on Aquaponics System" project by Rara R. et.al (2019) [12] was reviewed. In this project, aquaponic system water quality and water level monitoring, a TDS sensor, and an RTC sensor were used for the smart plant monitoring system.

3 Research methodology

In order to achieve full Smart Plant Monitoring System functionality, this project involves the design and development of a Wireless Aquaponic Automation and Monitoring System, Automation Plantation Control Unit System, and Mobile Dashboard & Notification System. In accordance with one of UiTM Cawangan Johor's catchphrases, Simfoni Alam, this project is carried out at the Faculty of Electrical Engineering's outdoor foyer Level 6, UiTM Cawangan Johor Kampus Pasir Gudang, which has sun array access as the pilot project platform for delivering sustainable food security and promoting UiTM Greenation in general. The parameter's data is gathered for at least one month in order to obtain Big Plant Condition Data with specific sampling times for data analysis and validation.

3.1 Development of smart plant monitoring system

The Power Supply Unit, Process Controller Unit, Plant Sensor Network System, Wireless Data Platform and Notification System are essential parts of this Smart Plant Monitoring System. As the system hardware is intended to be installed outside, it is combined with adequate safety standards that include all areas, such as the electrical/electronic standard and the weatherproof requirement. The complete block diagram architecture of the system is shown in Figure 1.

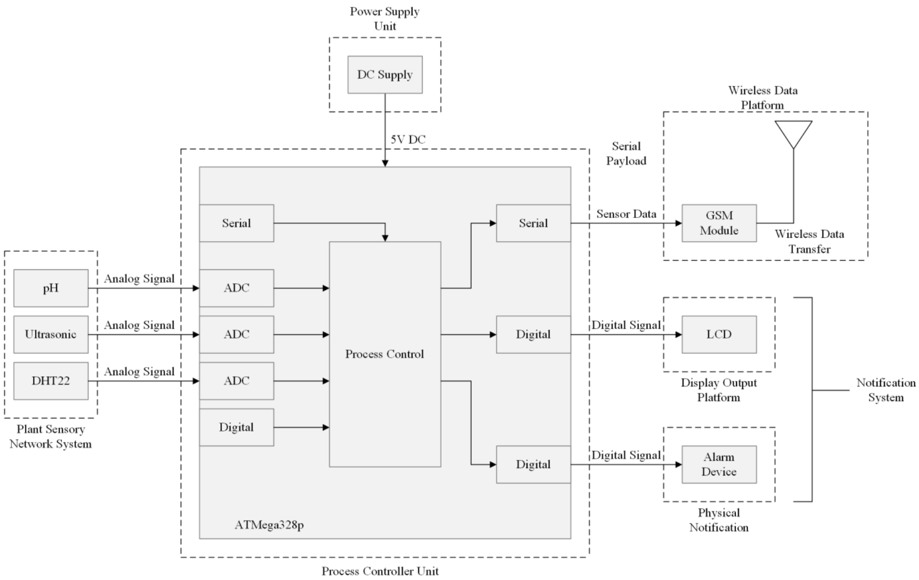

Fig. 1. Block diagram of smart plant monitoring system

3.2 Plant sensory network system

The sensory network for this system comprises of several sensors, including pH, humidity, and temperature sensors, as well as ultrasonic sensor, which measure the ambient temperature and humidity, water condition, and water level. The pH of the observed water is determined using an analogue pH sensor, with the sensor's output ranging from 0 (acidic) to 14 (alkaline). The DHT22 sensor measures ambient temperature and humidity. The water level is measured to ensure that the water supply is adequate for the growing plant system. The system is equipped with a GSM data transfer module that operates on the serial data communication protocol.

3.3 Process controller unit

The project uses the embedded processor ATMega328p as the main controller to process all the sensor data parameters and drive the actuator, which includes the LED indicator and water pump system. In order to digitize the required parameter value to the precise unit value, the Arduino IDE has utilized that programming with the C program to read the value of the data of the analog sensors via the ADC at specified time intervals. In order to communicate the processed data to the selected dashboard platform and display the necessary measured sensor data parameter, the controller is additionally integrated with the GSM Module of the controller. All water parameter data is wirelessly synchronized throughout each appropriate setup period for the owner's system to assess the gardening system.

3.4 Mobile dashboard and notification system

All of the processed data obtained from the designed plantation system is displayed on the mobile dashboard. Meanwhile, all the processed data from the plantation control is wirelessly transmitted, consequently with the setup period time to the mobile device via the serial communication using the GSM Module. The notifications are sent to the owner via SMS using the GSM Module. The owner can then view real-time data from the appropriate sensors, including water quality (pH), ambient temperature and humidity, and water level. Figure 2 displays a block diagram of the IoT dashboard's data visualization mechanism.

In addition, this Smart Plant Monitoring System includes a warning notification system that will alert the owner to take immediate preventative action if an operating parameter, such as water level or water condition (pH), is out of range. The relay module should be engaged by the controller to activate the alerting mechanism and power the warning buzzer and LED. During the process, the controller should also send the notification to the owner with the mobile dashboard, which has been installed earlier.

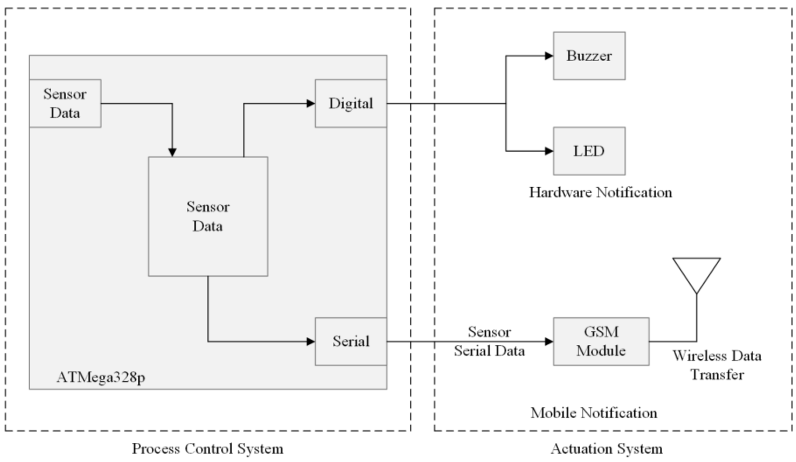

Fig. 2. The developed mobile dashboard for data visualization

3.5 System flowchart design

Figure 3 displays the flowchart for this Smart Plant Monitoring System. The analysis of all factors in this project started with the connection of the smartphone to the GSM module, as well as the LCD I2C display of temperature and pH measurements. The ultrasonic sensor will monitor the tank's water level. An SMS message will be sent if the water level falls below the average. If the water level is higher than usual, the buzzer and LED will activate. The 18-to-30-degree Celsius temperature range is detectable by the DHT22 sensor. If the temperature falls outside of the normal range, the buzzer and LED will turn on, and SMS notification will be issued automatically. The pH of the water is determined using the pH sensor. If the pH level is not between 6.5 and 8, the buzzer and LED will turn on automatically. When the GSM module is connected with the Arduino, the controller application will start up and all of the parameters will be displayed on the phone's screen.

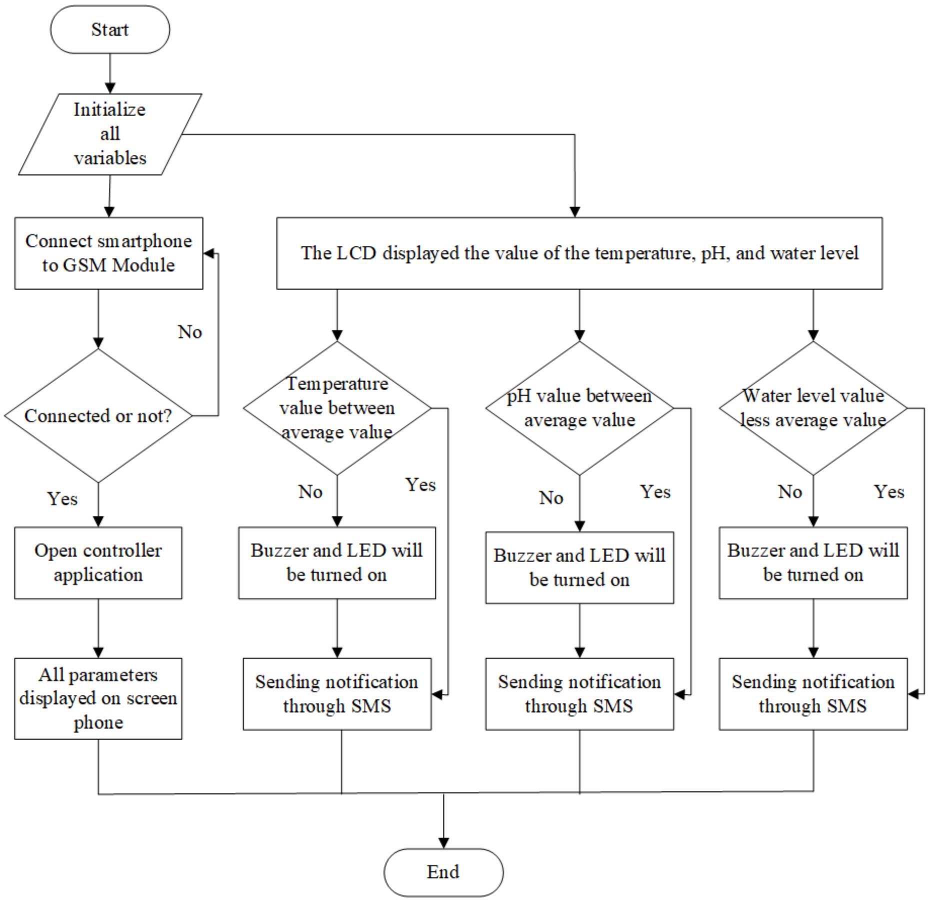

Fig. 3. The smart plant monitoring system operation flowchart

4 Result and discussion

The project's outcome can be divided into two parts: software design and hardware design. Several coding techniques will be discussed in the software section, depending on the hardware being used. GSM modules, pH sensors, temperature and humidity sensors (DHT22) are among the main sensor modules used in the project .

The coding shown in Figure 4 for humidity sensor (DHT22) is defined as DHTPIN 7. The data pin is connected to Arduino pin 7. DHT library, "DHT.h" is included in the coding to enable sensor reading. DHT dht(DHTPIN, DHTTYPE) was used to initialize the DHT library. The DHT library must be installed on the Arduino using the Adafruit

DHT library. "Float humidity" and "float temperature" are used to declare the DHT22 component. "dht.begin();" is used to indicate the initialized DHT module.

```
#include <SoftwareSerial.h>
#define DHTPIN 7
#define SensorPin A0
#include "DHT.h"
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd = LiquidCrystal_I2C(0x27, 16, 2);
SoftwareSerial mySerial(2, 3); //here software serial pin defined gsm
#define DHTTYPE DHT22
DHT dht(DHTPIN, DHTTYPE);

long duration, distancecm;
float temperature;
float humidity;
```

Fig. 4. Initialized code for temperature and humidity (DHT22) sensor

Once initialized, DHT sensor will start to operate and the humidity and temperature value were save at the respective variables as shown in Figure 5. The values will then be displayed at the LCD as well as sent to GSM according to the condition of the temperature. If the temperature senses more than 30 degree celcius, LED and buzzer will set to turn 'ON' and notification on temperature is 'HIGH' will be sent through GSM. While, if temperature sense less than 18 degree celcius, the notification on 'LOW' temperature will be post through GSM module.

```
humidity = dht.readHumidity();
//Read temperature in degree Celcuis
temperature  = dht.readTemperature();


if (isnan(humidity) || isnan(temperature)) {
  lcd.clear();
  lcd.setCursor(5, 0);
  lcd.print("Error");
  return;
}
```

Fig. 5. DHT22 module code to read the input sensor

Figure 6 shows the pseudocode for pH sensor reading which normally used to explain the overall coding for pH sensor. The snippet of the coding also shown in Figure 7 to indicate the algorithm used during sensor data conversion to pH value.

```
Pseudocode:
START
    SET variable phValue and avgValue
    READ sensor data 10 times.
    SORT input data small to large
    CONVERT analog input data to miliVolt
    COMPUTE phValue
    SHOW compute result
END
```

Fig. 6. Pseudocode for pH sensor reading

```
avgValue = 0;
for (int i = 2; i < 8; i++)                //t
  avgValue += buf[i];
//  float phValue=(float)avgValue*5.0/1024/6;
phValue = (float)avgValue * 5.0 / 1024 / 6; /
phValue = 3.5 * phValue;                   //c
Serial.print("    pH:");
Serial.print(phValue, 2);
Serial.println(" ");
```

Fig. 7. The algorithm used to convert sensor data to pH value

The pH sensors coding begins with ten samples of the analogue input A0. The code will arrange the samples data from small values to the largest samples value by using '*for*' loop function. The average value of six centre samples of pH is taken in this code. The code will then use to convert the analogue value to millivolts as shown in equation (1).

$$phValue = avgValue * 5.0/1024/6 \tag{1}$$

Then, to convert the millivolt value to the real pH value, the result needs to multiply with constant value as shown in equation (2).

$$phValue = 3.5 * phValue \tag{2}$$

The value is then sent to the serial port and shown in the serial monitor using serial.print.

Figure 8 shows the snippets of the GSM coding used to deliver the message. The GSM usually use AT command to send or read the message. The AT command, "mySerial.print("AT+CMGF=1");" is used to tell GSM module to change into text mode. Then, "mySerial.println("AT+CMGS="+601157148771"r");" code is basically used to set the number to send the message or short message service (SMS). The targeted phone number and the SIM card phone number of the hardware used on GSM module cannot be the same. The characters of the message can contain spaces and digits as the data type "String" is used to write. To conduct the test, the code as shown in Figure 8 is executed and sent to a phone number. The ASCII code for the GSM is "myserial.println((char)26);

```
void gsm6() {
//Secs the GSM Module in Text Mode //delay of
1000 milli seconds or 1 second
delay(1000);
// Replace your number gee The alert delay(1000);
mySerial.println(,,AT+CMGS=\"+601157148771\"\r ");

String dataMessage1 = ("Temp LOW: " + String (
temperature) + " C");
mySerial.println(dataMessage1);
// The SMS eexe you want to send delay (1000);
mySerial.println((char)26);
// ASCII code of CTRL+Z delay (1000)
}
```

Fig. 8. C++ Function to send DHT 22 sensor SMS using GSM

Figure 9 and Figure 10 show the front view of the Smart Plant Monitoring System with SMS Alert and the plan view of the system. In this project prototype, Brazilian Spinach plant type was used as the experiment.

Fig. 9. Smart plant monitoring system with SMS alert (front view)

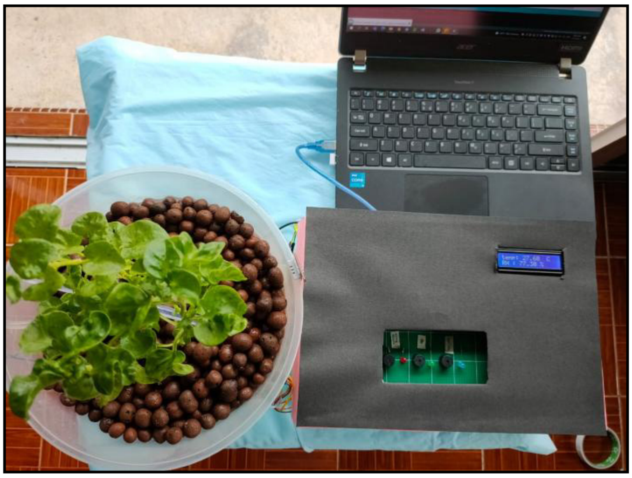

Fig. 10. Smart plant monitoring system with SMS alert (plan view)

When the system is ready, all data is processed by the microcontroller and then sent through GSM for data collection. Figure 11 shows the sensors output data displayed on the phone short message service (SMS). Information sent to GSM include humidity, temperature, pH value and distance to the measured water level.

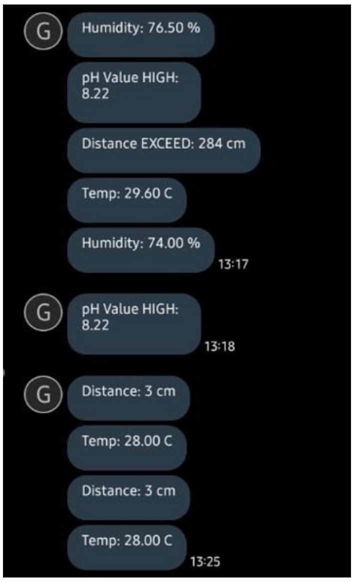

Fig. 11. Output for GSM

The data is collected to see how the plant's growth differed from the first to the last day of the experiment. Figure 12 shows a graph for the pH value in four weeks with the pH value ranged from 6.5 to 8. When the pH value is greater than 6.5, the water must be cleaned as it exceeded the value for the fish to live. Hence, to achieve a suitable pH value, the water must be cleaned for every three days.

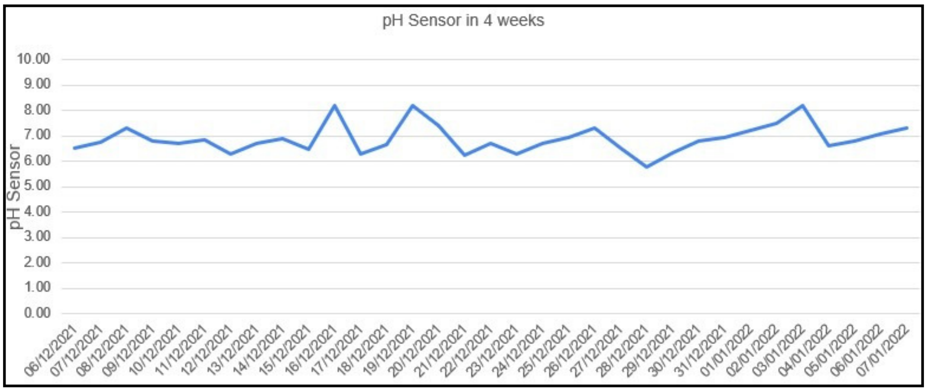

Fig. 12. Data collection for pH sensor in 4 weeks

The graph of temperature vs. humidity is shown in Figure 13. Humidity ensures that the plant received the right amount of moisture to continue growing. As a result of this experiment, Malaysia's humidity is steady and beneficial to plants. The temperature of the plants' surroundings has an impact on the humidity reading. Humidity decreases as the temperature rises.

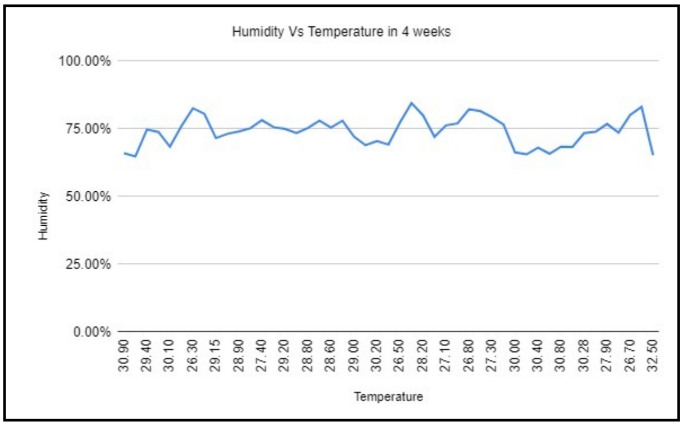

Fig. 13. Data collection for the temperature versus humidity in 4 weeks

Figure 14 and Figure 15 depicts the data collected for the height and diameter of the plant's leaf over a four-week period. The data collection begins around 9.30 cm height and 0.82 cm diameter. The plant's height (cm) and leaf diameter (cm) are both rising almost linearly as shown in Figure 14 and Figure 15. It indicates that the plant received enough nutrients in order to grow properly.

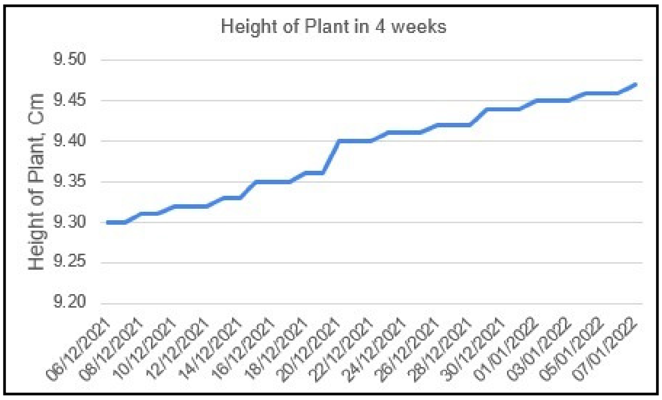

Fig. 14. Data collection for height of plant in 4 weeks

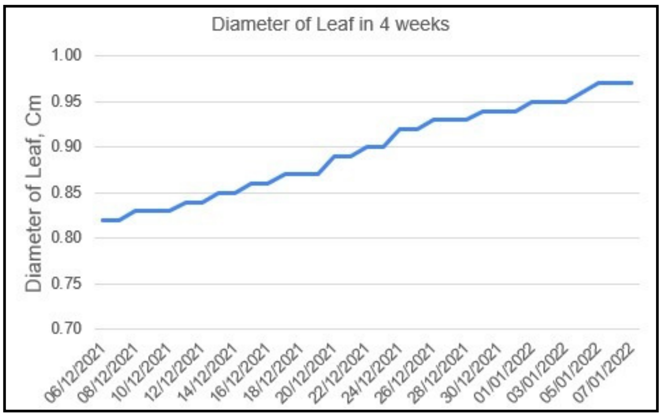

Fig. 15. Data collection for diameter of leaf in 4 weeks

Finally, Figure 16 illustrates a graph based on the water levels for the four-week period. The average height of the water level is 3 to 6 cm. If the distance between the plant and the water in the tank is high, the plant may not receive adequate water as it indicates that the tank is running low on water.

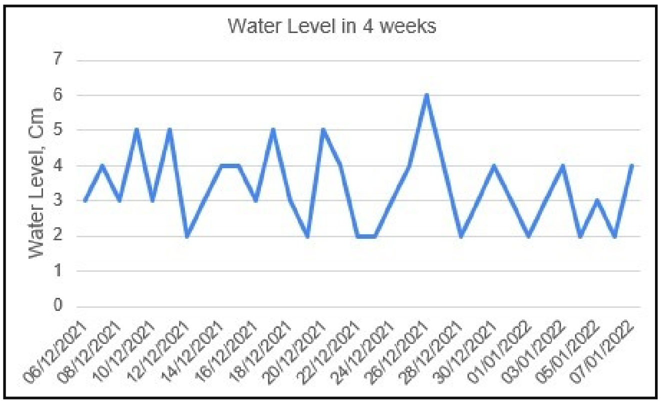

Fig. 16. Data collection for water level in 4 weeks

5 Conclusion

The data presented in this project are based on the concept of a Smart Plant Monitoring System to assist farmers in assessing the condition of their plants. This project was built with hardware that is compatible with current technologies. This initiative will also provide a wealth of new information. This prototype would assist farmers by sending SMS alerts about problems in their aquaponics systems. It allows farmers to simply monitor the condition of their plants. Furthermore, this project established an Internet of Things (IoTs) that continuously measured and presented to users all of the project's parameters, such as pH level, water level, humidity, and temperature. Some limitations of this prototype such as the use of GSM Module can be overcome by using updated IoT's facilities in future research.

6 Acknowledgement

The author would like to thank Universiti Teknologi MARA, Cawangan Johor for supporting this project under the Bestari Sepadanan Research Grant Scheme (600-UiTMCJ (PJIA. 5/2)).

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8 Authors

Zahari Abu Bakar obtained his Diploma in Electrical Engineering (Electronics) from UiTM Pulau Pinang, Bachelor of Electrical (Hons) Engineering and MSc. in Telecommunication and Information Engineering from UiTM Shah Alam. Currently, he serves as a senior lecturer at UiTM Cawangan Johor Kampus Pasir Gudang in Electronics Department. His main research interests are e-learning and Machine Learning.

Muhammad Zairil Muhammad Nor joined UiTM in April 2014 as an Electrical Engineering Lecturer in the Faculty of Electrical Engineering. He completed his Masters in Electrical Engineering (MEng) from the Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM) in 2013. His areas of expertise include Antenna Design, Reconfigurable Switching Mechanism, and Microwave Devices.

Kamaru Adzha Kadiran is a lecturer from UiTM Cawangan Johor Kampus Pasir Gudang in Electronics Department. He obtained his Bachelor of Engineering (Electrical - Telecommunications) (Hons) and Master of Engineering (Electrical - Electronics & Telecommunications) from Universiti Teknologi Malaysia (UTM). His main research interests are IC Design, Internet of Things (IoTs), Machine Learning and Embedded System.

Mohamad Farid Misnan is a Senior Lecturer from Universiti Teknologi MARA (UiTM) Cawangan Johor, Kampus Pasir Gudang. He completed his PhD in Electrical Engineering from the Faculty of Electrical Engineering, UiTM Shah Alam, in 2017. His areas of expertise include Robotic and Automation, Unmanned Aerial & Ground System, Sensory Network System, Internet of Things (IoTs), Embedded System and Machine Learning.

Maisarah Noorezam joined UiTM in March 2014 as an English Lecturer in the Academy of Language Studies. She completed her Masters in English Language Studies (ELS) from the Faculty of Social Science & Humanities, Universiti Kebangsaan Malaysia, in 2013. Her areas of expertise include applied linguistics, Teaching English as Second Language (TESL), and discourse analysis.

Article submitted 2022-08-09. Resubmitted 2022-09-15. Final acceptance 2022-09-17. Final version published as submitted by the authors.