IOT Hydroponics Management System

Chris Jordan G. Aliac', Elmer Maravillas ''
CCS Intelligent Systems Lab, CIT- University
N. Bacalso St. Cebu City

citbadrobot@gmail.com
elmer.maravillas@gmail.com

Abstract
This paper, an integrated system based on Internet of Things (IoT) for monitoring and management of the hydroponics garden is proposed. With the rising trend of IoT and through automation, the problems of managing these resources will be solved. This system aims to provide the ideal environment for plants to grow, a system where pH, water level, air temperature and relative humidity are constantly monitored. Additionally, with the use of simple mechanisms, this system provides controlled irrigation of water, and nutrient solution intake. Through the data gathered by the sensors and the use of cloud based technology as the backend, information is stored, managed, applied and shared via internet by users. Management of resources in a hydroponics set-up would become easier and more efficient based on the success and results of this study

***Index Terms*— IoT, sensors, web management, plants, hydroponics**

I. Introduction

This study focuses on making an Internet of Things (IoT) system that can manage the temperature, relative humidity, pH level, the inflow and outflow of water, and nutrient solution intake in a hydroponics system. The significance of hydroponics is in providing a way for an average person to grow their own food without the need of soil, especially for those people who are living in flats and inner city areas. Correct pH level, air temperature, relative humidity, PH level, nutrient level of the water, and correct irrigation of water is critically important in hydroponics. Therefore, the help of a management system that monitors these factors is valuable and will ensure higher success and efficiency rates of the grower. Hydroponics Management System (HMS) is a hydroponics system that enables users to control certain mechanisms for refilling, sprinkling, draining and many more thru the web application. They can also monitor the pH level, relative humidity, air temperature and water level, which is data collected from the sensors. As long as there is an internet connection available, the user should be able to monitor and control these anytime and anywhere.

Through HMS, hydroponics should become more accessible and available. This will allow busy people to grow their own food while managing and monitoring the system.

II. What is Hydroponics

Hydroponics is a subset of hydroculture, which is the growing of plants in a soil less medium, or an aquatic based environment. Hydroponic growing uses mineral nutrient solutions to feed the plants in water, without soil.

Hydroponic gardening involves growing plants in a nutrient solution rather than soil. The advantage of hydroponics is that you can avoid many of the problems that affect soil grown plants such as cutworms and soil-borne diseases that can ruin your crop. This means herbicides and pesticides can be avoided. Also you have more control over the nutrients that feed your plants. It is easier to vary the nutrients that the plant receives at various stages of its development to ensure optimum growth.

Instead of soil, a porous growing aggregate is used. This can include sand, vermiculite, gravel, coconut coir, clay balls or perlite. This allows air and nutrients to circulate more freely allowing a better distribution of oxygen and food to each plant. Nutrients and water are fed directly to the roots which enable the plant to spend more of its energy growing above the soil rather than pushing through soil to compete for nutrients. Because the roots are smaller the plants can be grown closer together thereby conserving space. This can mean everything grows faster and produces higher yields within a smaller space.

III. Methodology

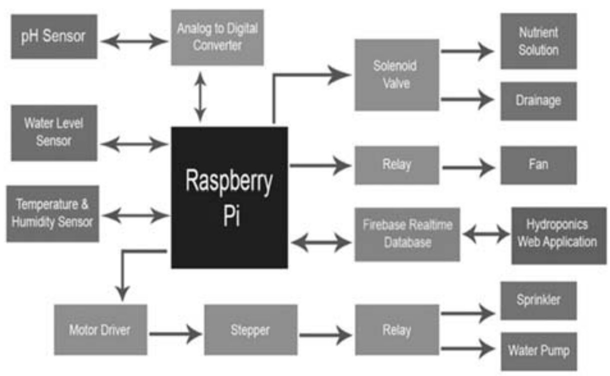

Fig. 1 General View of the Hardware System

The block diagram (above) shows the flow of data in the hydroponics hardware system. The Raspberry Pi is used to control the components in the hydroponics system based on the command that was retrieved from the Google Firebase a real time sensor logging system cloud service. The Raspberry Pi is also used to control the data retrieval from the sensors and the

978-1-5386-7767-4/18/$31.00 ©2018 IEEE.

data is then uploaded to Firebase. The data stored from Firebase is shown in the Hydroponics Web Application.

A. Raspberry pi (Raspberry Pi 3 Model B)

This small SOC ship board is programmed to get data from the Server, transmits data from the Temperature and Humidity Sensor, pH Level Sensor and Water Level Sensors to the Server. It is also used to control the fan, the sprinkler, the drainage, and the inflow of nutrient solution and water in the hydroponics system.

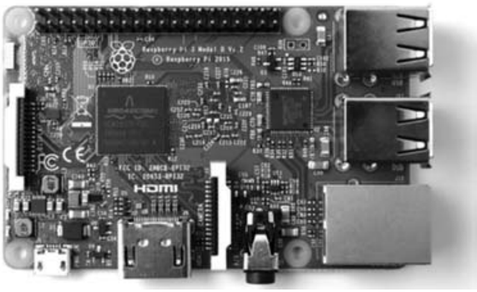

Figure 1.0 Raspberry pi (Raspberry Pi 3 Model B)

B. Water Pump (Venus Aqua 033F Aquarium Top Filter)

This is used to control the inflow of water in the system. Control of the water flow will be based on computation process from the SOC board based on other sensors.

Figure 2.0 Water Pump (Venus Aqua 033F Aquarium Top Filter)

C. Temperature and Humidity Sensor

These are the main sensors used to measure nutrient conditions of the system. IT is vital that these sensors be very accurate as it is the basis for the maintenance and sustenance of the plant's growth and health.

Figure 3.0 pH and temperature Sensor

D. Google Firebase

The Systems input and output functions are controlled by a web application supported by firebase node control systems and data logging systems. The systems control circuit (Raspberry Pi). Communicates to cloud services using either 3G, 4G and or WiFi connection whichever is available. The hardware control systems send data to Firebase in two modes, real- time and batch time. In real-time Systems, data from all sensors of the hardware system is sent continuously this applies to WiFi connections systems. When 3G or 4G LTE is used, data is logged into the memory of the control circuit and then is transmitted by batch to the cloud service in 1 hour increments. This method saves us from costly data charges.

Figure 4.0 System Management via Google Firebase

The mode of communication to and from Google Firebase is via JSON API code which is written on an Python code within the Linux Operating system running on the Raspberry Pi hardware.

E. System Management Via Internet Website App

Data from the Firebase cloud service is then extracted and used display data on an Internet website app. The app is design to me both desktop and mobile friendly. Data is presented to the app as a simple dashboard for the different sensors used in the system. Control buttons are also used in the app to control the hardware system in real-time or on a scheduled time. Manual control operations are also found on the app to control the hardware system in a manual basis.

IV. Testing/ Data gathering Methods

The following testing methods were used for gathering data from the system. This also measure the quality of the system as how good it is able to grow plants. Aside from the sensors data systems, the test will also perform data distribution to and from the internet web server.

A. Sensor Data Acquisition Time

This test is conducted to measure the time it takes for the Raspberry Pi to gather data from the ultrasonic ranging sensor, temperature and relative humidity sensor, and the pH level sensor

B. Effect of the Fan and the Sprinkler to Relative Humidity and Air Temperature

This test is conducted to check if the Fan has the ability to decrease the Relative Humidity of the surroundings. And also check if the Sprinkler has the ability to increase the Relative Humidity of the surroundings

C. Hydroponics System, Firebase and Web Application Connectivity

This test is conducted to check if the Web Application has the ability to control the components in the hydroponics system by sending commands to the hydroponics system through the Firebase Real-time Database.

D. pH Sensor Reliability Test

This test is conducted to determine the margin of error of the pH Sensor by using pH buffer solutions. This is used to determine the reliability of the data gathered from the pH Sensor. The Percent Error and Margin of Error are computed using the equation:

*Percent Error = (pH buffer used - Average pH level) * 100*
Margin of Error = pH buffer used - Average pH level

eq 1.0

V. RESULTS

A. Sensor Data Acquisition Time Results

TABLE 1.0
DATA LATENCY TIMES TO AND FROM SOC AND SENSORS

Sensor	Sensor Data Acquisition (ms)			
	Sample 1	Sample 2	Sample 3	Average Time
DHT22	0.318748	0.32763	0.2783	0.308226
HC-SR04	0.344603	0.346016	0.357159	0.349259
Note: HC-SR04 data acquisition measured at distance 6cm				

Table 1.0 shows the system's processing time from the different sensors to the Raspberry Pi. This table shows the time it takes for the Raspberry Pi to gather data from the sensors.

B. Effect of the Fan and the Sprinkler to Relative Humidity and Air Temperature

TABLE 2.0
EFFECT OF FAN RELATIVE TO SENSORS

Fan	First Sampling		Second Sampling	
	Temperature (°C)	Relative Humidity (%)	Temperature (°C)	Relative Humidity (%)
Initial Data	29.9	65.02	30.6	63.35
Data at 5 minutes	29.98	64.7	30.53	63.3
Data at 10 minutes	30.1	63.76	30.4	63.6
Data at 15 minutes	30.2	64.2	30.45	62.75
Data at 20 minutes	30.38	63.6	30.53	62.25
Note: The temperature and humidity sampled is taken at 10AM to 12NN. Ideal temperature range – 18.33°C to 26.67°C Ideal relative humidity – 50% to 80%				

Table 2.0 shows the effect of turning ON the Fan for 20 minutes to the Air Temperature and the Relative Humidity of the hydroponics system. After 20 minutes, there is only a decrease of 2.26% in the Relative Humidity and a 0.28°C increase in the Air Temperature.

C. Hydroponics System, Firebase and Web Application Connectivity

TABLE 3.0
COMMAND (ACK) SEND CONNECTIVITY

Command	Usage	Remarks
Get Water Level Data	Command used to trigger the raspberry pi to collect data from the HC-SR04 sensor and to send the data to the Firebase database.	OK
Get Temperature Data	Command used to trigger the raspberry pi to collect data from the DHT22 sensor and to send the data to the Firebase database.	OK
Get Humidity Data	Command used to trigger the raspberry pi to collect data from the DHT22 sensor and to send the data to the Firebase database.	OK
Get pH Level Data	Command used to trigger the raspberry pi to collect data from the pH Level sensor and to send the data to the Firebase database.	OK
Control Water Pump	Command used to Start the Water Pump and to Stop the Water Pump once the desired water level is achieved. The Water Level is also sent to the Firebase database every 2 seconds.	OK
Control Drainage	Command used to Drain the water in the hydroponics system and to Stop the draining once the desired water level is achieved. After draining the water, Control Water Pump command is called to replenish the water and nutrient solution in the hydroponics system. The Water Level is also sent to the Firebase database every 2 seconds.	OK
Control Fan	Command used to Start the Fan and to Stop the Fan once the desired temperature is achieved. The temperature is also sent to the Firebase database every 2 seconds.	OK
Control Sprinkler	Command used to Start the Sprinkler and to Stop the Sprinkler once the desired humidity is achieved. The humidity is also sent to the Firebase database every 2 seconds.	OK

In Table 3.0, the commands used by the web application to control the hydroponics system are shown. The commands and data collected from the system are stored in the Firebase database. The Get Commands are used to get the data from the sensors in the hydroponics system and update the data in the Firebase database. The Control Commands are used to control the components in the hydroponics system while at the same time; it also updates the Firebase database.

D. pH Sensor Reliability Test

TABLE 4.0
PH Sensor Test

Samples	ph 7	ph 10	ph 4
Sample 1	6.80	9.94	3.87
Sample 2	6.81	9.90	3.82
Sample 3	6.70	9.91	3.80
Sample 4	6.68	9.92	3.78
Sample 5	6.77	9.91	3.77
Sample 6	6.76	9.92	3.79
Sample 7	6.75	9.90	3.85
Sample 8	6.78	9.93	3.77
Sample 9	6.79	9.91	3.77
Sample 10	6.78	9.91	3.76
Average	**6.762**	**9.915**	**3.798**
Percent Error	**3%**	**1%**	**5%**
Margin of Error	**± 0.238**	**± 0.085**	**±0.202**

Table 4.0 shows the pH level data gathered from the pH module when it was tested to the pH 4, pH 7 and pH 10 buffer solutions. The margin of error of the pH sensor is computed to check the condition of the pH sensor.

E. Prototype System Hardware

Figure 5.0 Partial Hardware Prototype (before plant test)

The Hardware Prototype shown above (Figure 5.0), is a simple assembly with partial positions of the sensors, control circuit and actuators connected and placed on the system. The prototype simply illustrates as a test for the functionalities of the system in response to the remote management software via the website app. The figure contains the basic essentials for the operation of features of the system. Actual test will be conducted once the entire system focuses on a specific crop to grow.

F. Control and Monitoring Website App

Figure 5.0 Control and Monitoring Website App

Figure 5.0 shows the main page of the remote control management and monitoring website app. The site was written on HTML 5.0 with CSS and run by JSON, JavaScript and PHP on the back end connecting to Google Firebase. Figure 5.2 (below) shows the system monitoring page. The monitoring page shows the data coming from the system hardware mainly the water level, PH level of the water, air temperature and air humidity levels. A warning system was also built to notify the user that the condition levels are too high or too low. Indication for the type of crop and its recommended conditions are found on the settings page shown below. (figure 5.2) Based on the warning notifications, the appropriate suggestions for mitigation is given to the user for manual and or automatic control if chosen.

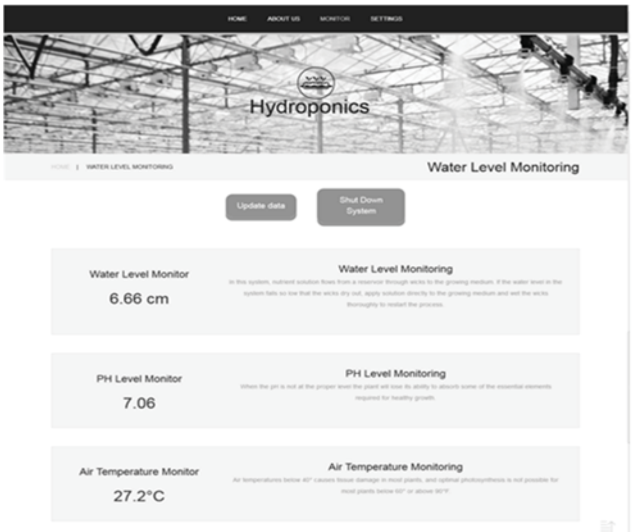

Figure 5.1 Monitoring Page

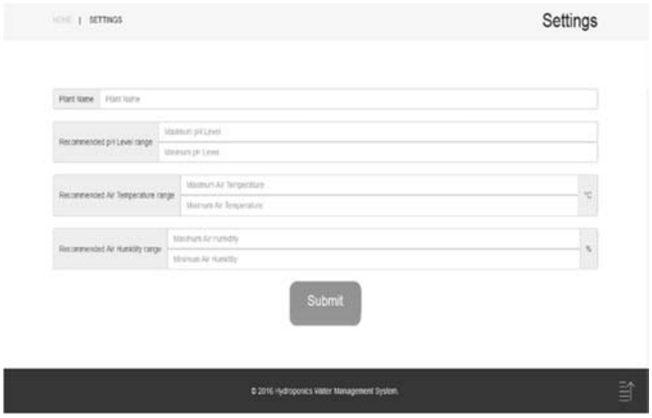

Figure 5.2 Settings Page

VI. CONCLUSION/ RECOMMENDATION

Based from the implementation of this Hydroponics Management System, it can be inferred that our system is capable of sustaining life of plants. Based on the data gathered and tests conducted by our team, we were able to come up with a fully functional system. The web application was able to control the drainage, fan, sprinkler, and water pump of the hydroponics system. The web application can also successfully gather data collected from the pH level sensor, water level sensor, air temperature and humidity sensor. In the other hand, the fan and sprinkler did not meet the ideal temperature and relative humidity range for hydroponics growing plants. The data collected from the pH module has a larger margin of error when it is tested in the pH 4 and pH 7 buffer solutions.

Since the objective of this project is to build a simple and cheap Hydroponics Management System, most of the components used are DIYs. There are a lot of suggestions for improvements. First, choose a water pump with greater water pressure for the sprinkler to have greater area coverage. The placement of the water pump in the hydroponics system should also be considered so that the water pump would stop refilling after the pump is turned off. The future proponents of this research have to consider the vacuum that forms after the water pump is turned off. In the diluting process, the future proponents' needs to know the exact computation for the amount of water needed to be drained in order for the pH level to decrease. The user also needs to input the nutrient ranges in the hydroponics solution to help in the drain height computation.

The hydroponics system needs to be a closed system for the sprinkler and fan to work. In the closed hydroponics system, you can now easily control the temperature and relative humidity with the help of the sprinkler and the fan. The sprinkler needs to have finer holes for the sprinkler to produce finer mist that would contribute to increasing the relative humidity of the area. The fan also needs to be large enough depending on your hydroponics system area. When in a close system, air exhaust should also be considered for temperature and humidity issues. If you insist on having an open hydroponics system, remove the fan and sprinkler.

REFERENCES

[1] DiCola, Tony. "Raspberry Pi Analog to Digital Converters." https://learn.adafruit.com/raspberry-pi-analog-to-digital-converters/mcp3008#software-spi

[2] "Raspberry Pi ADC: MCP3008 Analog to Digital Converter." https://pimylifeup.com/raspberry-pi-adc/

[3] Monk, Simon. "Adafruit's Raspberry Pi Lesson 10. Stepper Motors." https://learn.adafruit.com/adafruits-raspberry-pi-lesson-10-stepper-motors/hardware-uln2803

[4] Nedelkovski , Dejan. "Control High Voltage Devices – Arduino Relay Tutorial." http://howtomechatronics.com/tutorials/arduino/control-high-voltage-devices-arduino-relay-tutorial/

[5] Kartha, Vivek. "Interfacing HC-SR04 Ultrasonic Sensor with Raspberry Pi." https://electrosome.com/hc-sr04-ultrasonic-sensor-raspberry-pi/

[6] Griffiths, Mark. "The design and implementation of a hydroponics control system." Oulu University of Applied Sciences. Autumn 2014.