

Solar Powered Vertical Hydroponic Farming using Internet of Things (IoT)

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Abstract - For hydroponic farmers, this system was developed to create a vertical hydroponic farm with water level, PH level, humidity-temperature monitoring, and automatic watering using IoT. The system was created by the researchers using a prototyping methodology. This technology is made to give the farmer a simple way to use the internet on their cell phone to monitor their vertical hydroponic farm. Using ISO 25010, an international standard for software evaluation, the system was assessed. Even though they were far from their farm, the system allowed the farmers to keep an eye on the condition of their hydroponic farm. They may check the PH level, water level, temperature, and humidity of their hydroponic farm using a mobile device that is internet-connected. The mobile monitoring app, which shows the farmer's phone the value of the sensor reading from the vertical hydroponic farm and the moment the data was retrieved, requires the farmer to have internet connectivity. This was done in an effort to create a better Internet of Things (IoT)-based vertical hydroponic farm system for use in residences and businesses. Sensors are now able to gather data, which can then be digitally analyzed from anywhere in the world. For those who are new to the field, utilizing an Arduino microcontroller (MCU) is simple and enjoyable. Here is an example of PH level, water level, humidity, and temperature monitoring in the field of agriculture using an Arduino Wemos D1 Wi-Fi Hardware and the Internet of Things.

Keywords: *Internet of Things (IoT), Vertical Hydroponic Farm, Arduino Wemos D1, Ph Sensor.*

1. INTRODUCTION

Hydroponic gardens are now famous, especially among people who love planting or farming but only have limited space in their home to make a vegetable garden. Hydroponics is a type of gardening method in which you can grow a plant without soil by only using a chemical solution mixed with water. The in-farm sensors collect and record farm data and allow users to remotely monitor crop growth via smartphones.

According to Kuyanuth Kularbphettong, et al., 2019, Hydroponics is a growing plant system that does not use soil but uses water with nutrients to save space for planting and is not contaminated with chemicals in the soil. Hydroponics has a number of innovative techniques that are not limited to plant with water culture, like the nutrient film technique, the deep flow technique, the dynamic root floating technique, etc.

The Internet of Things is a technological innovation where machines, devices, appliances, etc. are controlled or monitored by computers or mobile phones using the Internet. It is communication between the device and the cloud and device to device. IoT is widely used these days, whether in projects, commercials, households, or industries. The Internet of Things is used for smart control and automation with the help of sensors embedded into its physical structure.

Hydroponic farming or gardening uses electronic devices with relays to cycle the water with a mixed solution so that the plants can grow with the nutrients they need without soil, which is commonly called the "active system." Most of the hydroponic design is

horizontal, where water flows horizontally back to the water tank using a water pump controlled by a relay. But most of the problems encountered in hydroponic farming are that farmers need to maintain a controlled growing environment for plants, such as lighting, temperature, nutrient solution PH level, and electrical conductivity, because they affect the growth of the plant. In horizontal hydroponics, the water is stored below the roots of the plants, where algae grow and become messy and dirty. This may increase the risk of spreading disease to your hydroponic system. The other problem on hydroponic farms is power outages or blackouts. If there is a power blackout for a day, the hydroponic system will stop pumping water that cycles to the plants, which may cause plants to die for a day without water cycling to their roots.

Triston Hooks et al. (2022) stated that during summer or winter, greenhouse production of cool-season crops such as lettuce and pak choi using deep-water culture systems and nutrient solution cooling or heating to a target temperature of 24 °C increased shoot biomass and total leaf area compared with control. Spinach was the most heat-sensitive species, and solution cooling to 24 °C was not sufficient for marketable growth. However, both lettuce and pak choi can be effectively grown during the summer with nutrient solution cooling. Likewise, nutrient solution heating during the winter season increased lettuce plant growth with a relatively low air temperature setting in the greenhouse to reduce heating costs. Overall, more research is needed for optimization of the nutrient solution temperature range for both cooling and heating of various high-value baby leafy greens.

According to Daniel P. Gillespie et al., hydroponic leafy greens are grown in nutrient solutions with pH 5.5 to 6.5. Lower pH may inhibit plant growth, whereas pathogenic oomycete growth and reproduction may be mitigated. pH effects on nutrient availability: high pH nutrient solutions diminish leaf and root growth. Plants grown in high-pH nutrient solutions developed clusters of short, highly branched roots.

A vertical hydroponic farm with water level, PH level, humidity, and temperature monitoring with automatic watering using IoT is a technological innovation, or what we called Agri-Tech, that could help hydroponic farmers monitor their hydroponic garden or farm using Arduino hardware and sensors and the Internet of Things viewed in a mobile app. This type of hydroponic garden is designed vertically so that the water can flow directly to the roots of the plants and back to the water tank. It has a PH level sensor to monitor the PH level of the water solution and a humidity and temperature sensor to monitor the humidity and temperature status of the garden. If the humidity is low, it will activate the humidifier, and if the temperature is too high for the plant, the system will activate the cooling fan. The entire sensor reading that is displayed on the LCD display is sent to the mobile app using the Internet, so that it is easy for the hydroponic farmer to monitor the status of his hydroponic farm. This type of hydroponic system is powered by solar energy, which is a renewable type of energy source, so that if there is a power blackout, the hydroponic system still operates and pumps water that cycles inside the hydroponic PVC pipe.

II. METHODOLOGY

Conceptual Framework

The input-process-output IPO model refers to the representation of all the factors that make up a process. In the IPO diagram, it includes all of the materials and information that are required in the process, the specific details of the process itself, and the descriptions of all products and by-products anchored on the process that took place (Isagani Costales Canonizado, October 3, 2021).

Figure 1 shows and discusses the specific input or variable needed by the system and the procedures, or what should be done with such a variable to make it useful or essential to the system.

The input based on the figure is that the sensors are controlled by Arduino Wemos D1 WiFi hardware, where the sensors are the DHT sensor for humidity and temperature readings and the PH sensor to monitor the acidity level of mixed solutions that flow in the vertical hydroponic garden. Buzzer to alarm if the humidity, temperature, or Ph level exceeds or falls below normal levels; cooling fan and humidifier to normalize the temperature and humidity; peristaltic pump to pump Ph+ and Ph- to normalize the Ph level.

The process of the system is that the data readings of the sensor are displayed on an LCD screen outside the system for nearby monitoring, and all the sensor readings are also sent to the Android application using the Internet of Things.

Then the output would be solar-powered vertical hydroponic farming using the Internet of Things (IoT).

The researchers used ISO 25010 to evaluate the system for the following characteristics: functionality, reliability, usability, efficiency, maintainability, and portability.

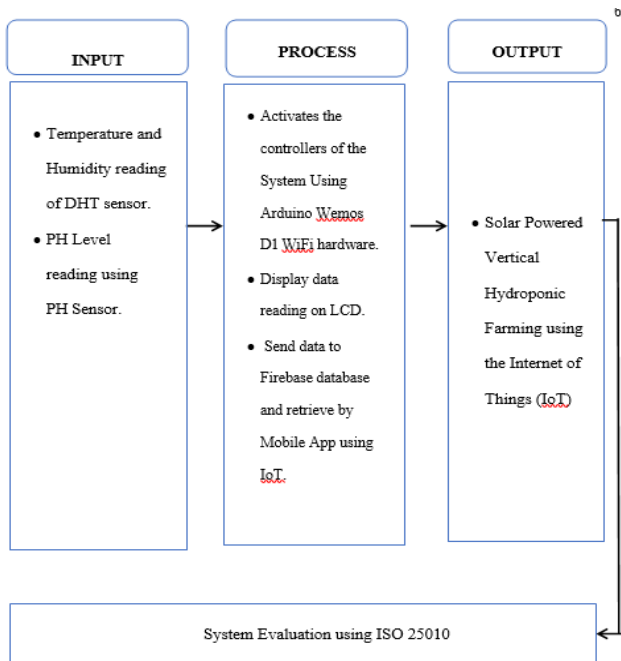


Figure 1. The Conceptual Framework of a Vertical Hydroponic Farm with water level, PH level and humidity-temperature monitoring with automatic watering using IoT.

Methodology is the systematic, theoretical analysis or the methods applied to the field of study. It comprises the theoretical analysis of the body or methods and principles associated with a bunch of knowledge.

In this chapter, the methods used in creating and innovating Solar Powered Vertical Hydroponic Farming using Internet of Things (IoT) are presented to generate usability and efficiency of the system. It consists of (1) Project Description, which describes the system, its function and how it works; (2) Requirements Analysis, which contains different diagrams of the system; (3) Design Specification, which contains the user interface of the system; (4) Testing and Operation, which states the method used and (5) Project Evaluation, which is based in ISO 25010.

Project Description

Solar Powered Vertical Hydroponic Farming using Internet of Things (IoT) is a system that is powered by a solar energy and has temperature and humidity monitoring, PH Level monitoring that is displayed in the LCD Shield and viewed in mobile phones using Internet of Things. It has also an automatic watering system using Arduino Wemos D1 Hardware that cycles within the Hydroponic Farm. This system aims to provide a simple solution in Monitoring System and water solution cycle using programmable hardware that is powered by solar energy. This system also aims to implement the IoT technology innovation as a business and farming solution.

Development Process

In developing the system, the researcher used the prototyping based model. The system has passed a series of test and revisions until it could meet the exact function and purpose of the study.

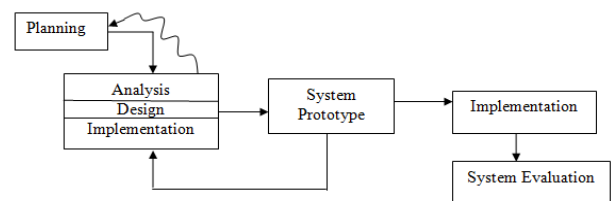


Fig-1.1 the Prototyping-base Model

Fig2. The Prototyping-base Model

The Prototyping Model is a system development method (SDM) in which a prototype (an early approximation of a final system or product) is built, tested and then reworked as necessary until an acceptable prototype is finally achieved from which the complete system or product can be developed. It is an interactive, trial and error process that takes place between the developers and users.

In this world, the developers could build a prototype of the system before they could create the final system. It begins with the planning phase where the beginning of the system came from a single idea and expanded. The expanded idea was analyzed if it is possible to achieve, what are the reasons why it should be created, what are the benefits it could give to the user. The system should also be analyzed on how it goes and how it works. The next phase is Design Phase where the system prototype would be designed according to its use.

Planning

In this stage, the researchers gathered data, visualized the outcome of the system, and organized the system according to its function. The researcher gathered information about the function of

Hydroponic System and how to combine the Internet of Things to innovate the monitoring system of ordinary Hydroponic Farm and powered it with solar energy.

Analysis

In this study the researchers used to gather data, visualize the outcome of the system and organizing the system according to its function. The researchers gathered information about the function of egg incubator and how to combine the Internet of Things to innovate the monitoring system of ordinary egg incubator.

Design

The researcher planned the design of the system, in terms of functionality, outcome and appearance. In designing the systems' architecture, the researchers used the Unified Modeling Language (UML) which includes Activity Diagram, Use Case Diagram, Sequence Diagram and Deployment Diagram.

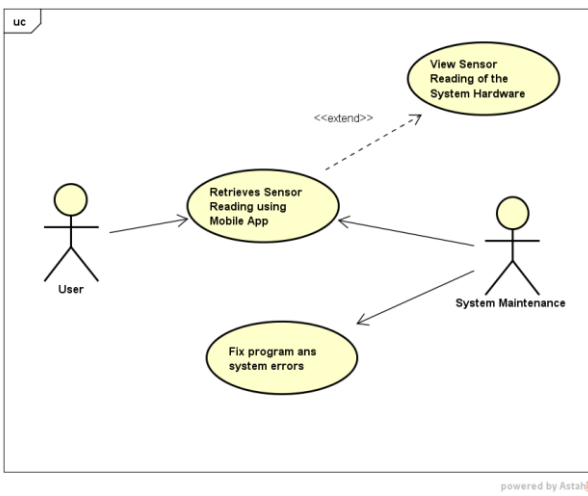


Fig 1.2 Use Case Diagram of the User and Admin/Maintenance of Solar Powered Vertical Hydroponic Farming using Internet of Things (IoT)

Figure 1.2 shows the use case diagram of Solar Powered Vertical Hydroponic Farming using Internet of Things (IoT). The User/Farmer and System maintenance can view the Realtime sensor reading status of Hydroponic farm using mobile retrieved from a Firebase database. The system maintenance is the one who is responsible of fixing system failure, program error and system upgrade.

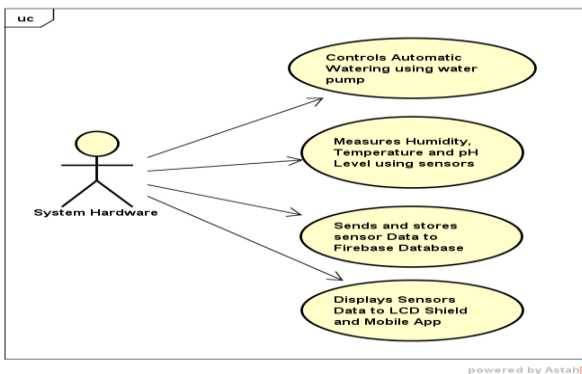


Fig 1.3 Use Case Diagram of the System of Solar Powered Vertical Hydroponic Farming using Internet of Things (IoT).

Figure 1.3 shows the use case diagram of Vertical Hydroponic Farm with PH level and humidity-temperature monitoring with automatic watering system using IoT. The System can control the automatic controls of the devices such as Dozer for balancing water pH Level, Humidifier for Humidity and Cooling fan for temperature, and it has water pump that pumps water from tank to the plants. It has sensors that measure sensor reading and LCD Shield that displays status of Hydroponic farm and has firebase database that sends sensor real-time data to Android Application.

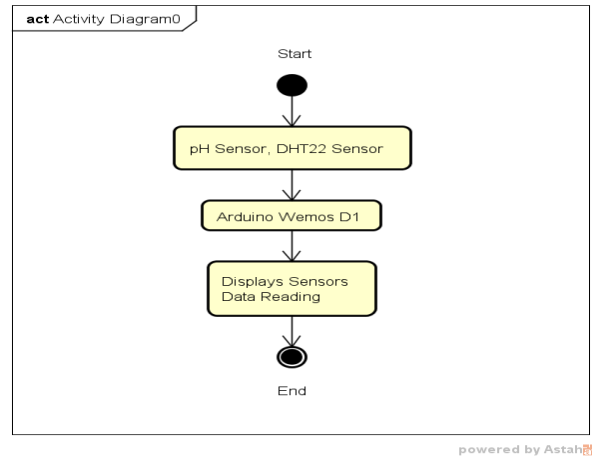


Figure 1.4 Solar Powered Vertical Hydroponic Farming using Internet of Things (IoT) Monitoring Activity Diagram.

The Figure shows the activity of Vertical Hydroponic Farm Manual System monitoring. The PH sensor, Water level sensor and temperature and humidity sensor reads the data using Arduino Wemos D1 R1 and displays the data in the LCD Shield.

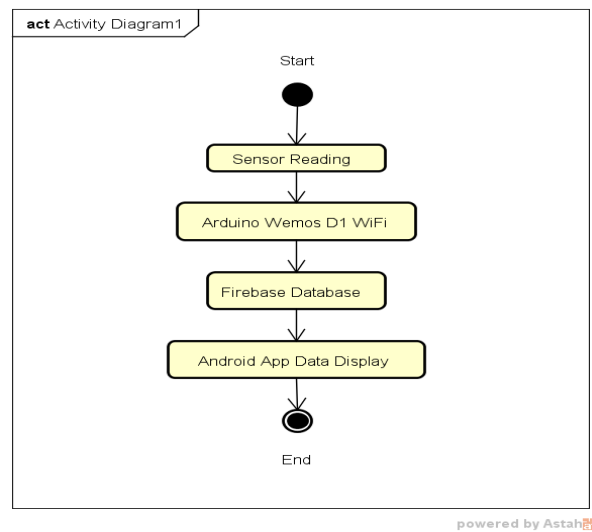


Figure 1.5 Vertical Hydroponic Farm with water level, PH level and humidity-temperature monitoring with automatic watering using IoT Activity Diagram.

The Figure shows the activity of the Sensor reading monitoring using Internet of Things. The sensors of the system send the data reading using Arduino Wemos D1 R1 WiFi to Firebase database. The Firebase store sensor data which is retrieve by an Android application using JSON. The data displays on Android Application which can be viewed by the user if the smart phone that is used is connected to an Internet.

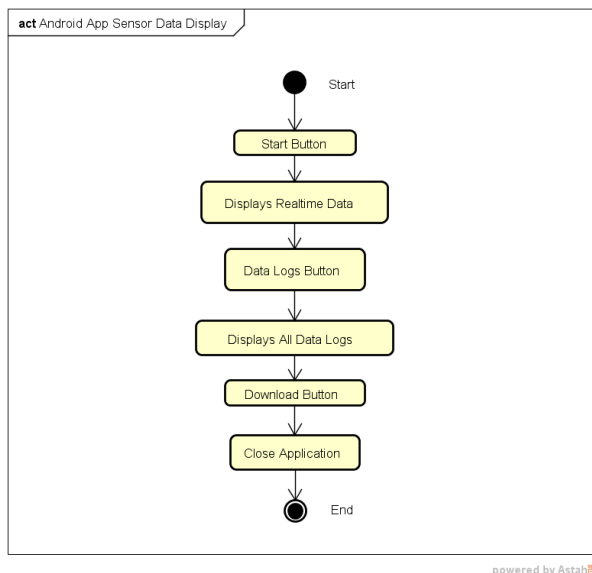


Figure 1.6 Activity Diagram of Sensor Monitoring Android App.

The Figure shows the activity of the Sensor Monitoring Android App. When the user open or turn on its Mobile data or Internet Connection before clicking the Monitoring icon in using the application. If the android phone is connected to the internet, the user can monitor the system by clicking the Start button, and then the real-time data is displayed on Android Phone's Screen. The Android phone has data logs button which displays all sensors data from oldest to latest, and then the user can download the data in CSV File and use it for Statistical analysis.

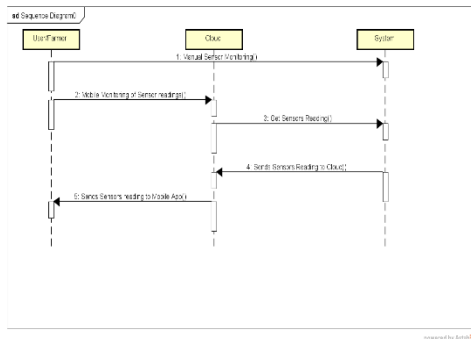


Figure 1.7 Sequence Diagram of the system.

The Sequence diagram shows where User can monitor the sensor readings of the system manually or through an android phone. The System controls and check the humidity and temperature, and PH Level with the use of a sensors and it displays the data in the LCD Shield for manual monitoring and sends data to mobile phones app with the use of Internet of Things.

Deployment Diagram

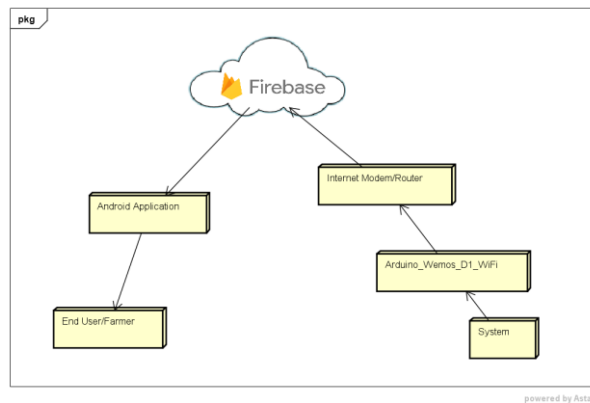


Figure 1.8 Deployment Diagram of the system:

The Figure shows the deployment diagram of the system. The system is connected to the Internet of Things. It is the tool for sending and receiving monitored data of sensor to the user and maintenance of the system. As the device is programmed for the system's use, transactions for sending and receiving of sensor readings are the User and Admin/Maintenance of the system. From the System hardware that is connected to a WiFi it sends data to the Cloud Database, the database stores the data so that the Android Phone can retrieve the data in real-time and from oldest to latest, which can be useful to the user in terms of far location monitoring.

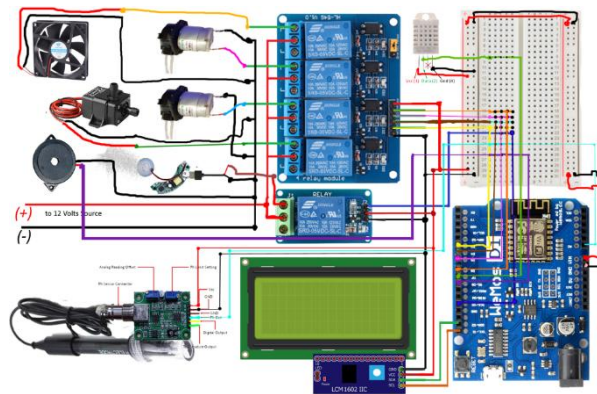


Figure 1.9 Circuit Diagram of the System Hardware

Figure 1.9 shows the circuit diagram of the System Hardware. Where all the components, sensors and devices are connected to Arduino Wemos D1 R1 Programmable microcontroller. The hardware has a DHT22 Sensor for Humidity and Temperature reading, Ph Sensor for water Ph level reading, Mini Water Pump to circulate the water from tank to hydroponic tower, doser pump to pump pH solution if the pH is imbalance. Cooling fan to cool down the plants if the temperature is too high and humidifier to balance the humidity of the hydroponics environment and buzzer to alarm if either the Humidity, Temperature or Ph level is High or Low. It also has LCD Shield to show all sensors reading value.

Design Specification



Fig. 1.10 Vertical Hydroponic Farm with water level, PH level and humidity-temperature monitoring with automatic watering using IoT

Figure 1.10 shows the prototype of the system with Arduino Wemos D1 as the main controller of the system. The system has an LCD shield for data reading display, DHT sensor to read humidity and Temperature value, PH Level Sensor for PH Level reading, and relay module for fan, cooling system, pump, dozers and Humidifier. The system has a buzzer for alarm if the PH is too High or too Low then the doser activates to balance the water ph level inside the tank, same with temperature if too high or too low the buzzer with alarm then the fan activates to cool down the temperature and also with humidity which activates humidifier if the humidity is too low, so that the plant in the hydroponics system can grow in normal ph level, humidity and temperature.



Fig 1.11 PH Level, and Temperature and Humidity Monitoring of prototype Vertical Hydroponic Farm with water level, PH level and humidity-temperature monitoring with automatic watering using IoT.

The figure showed the Sensors reading Value that is preview on the LCD Shield. The system has DHT Sensor that reads Humidity and Temperature, and Ph Sensor that Reads Ph level of the Water inside the Tank. It has Arduino Wemos D1 R1 that controls all the sensors and devices of the System Hardware and sends the data to the Cloud and it is retrieved by the Mobile App with the use of Internet.

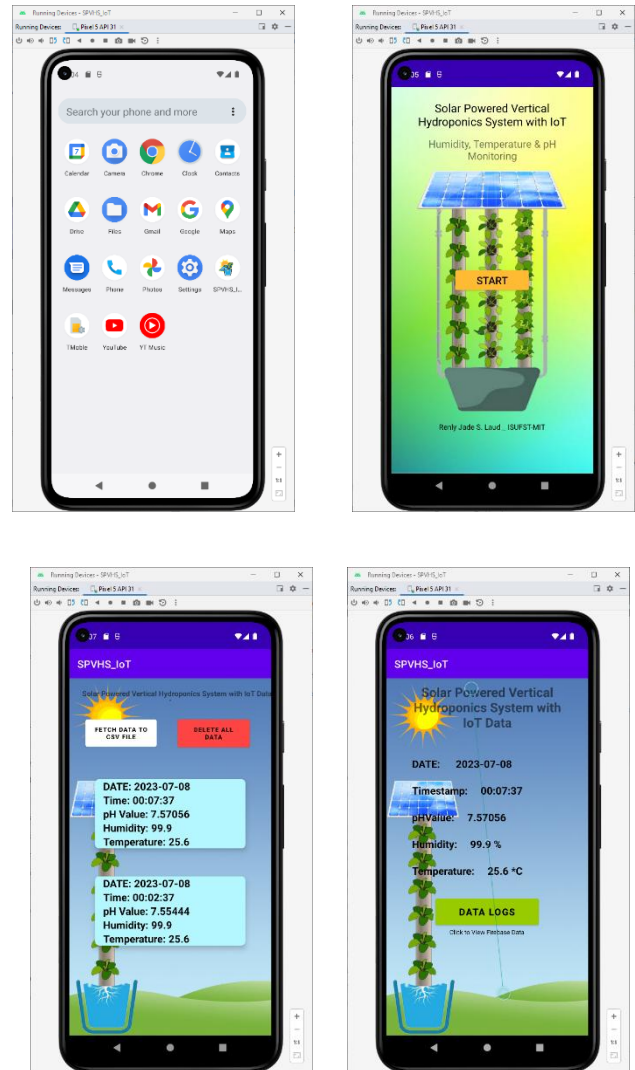


Figure 1.12. Android Application of the System.

The figure shows the Android Application of the System which is developed using Android Studio. The Android App is the one who is responsible of retrieving the data from the Firebase Database that was sent by the hardware using Internet of Things. The Android app displays the real-time data and it has data logs of previous to latest data readings of sensor, it also had download button where you can download the data from firebase database in CSV File format for future references of growing your plant in hydroponic tower.

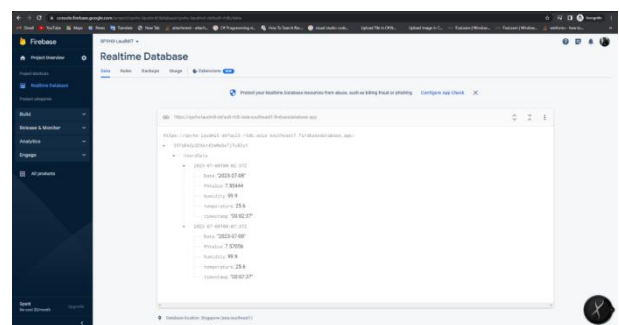


Figure 1.13. Firebase Real-time Database of the System.

The figure shows the Firebase Real-time Database of the System.. The Firebase Real-time Database is the one who is responsible of storing the data that was sent by the hardware using Internet of Things. The Firebase Real-time Database stores all the real-time data to be fetch by the Android App for mobile monitoring purposes.

Implementation

In this stage, the researcher started to create and develop a system through the process of experimentation, testing, coding, trial and error methods.

Testing and Operation

The main controller was tested if it works with the motor pump for water solution cycle for watering system and sensors are calibrated. In the part of the hardware and sensor, the researchers programmed a code that will activate the Arduino Wemos D1 for data gathering of the sensor and for sending data to cloud and retrieve by a mobile app using Internet. The program code was done in the process of trial and error until the target output was reached. The IoT was also tested if it could get and post data to the internet, and the Mobile app was tested according to its functionality. The testing of the system focused on the requirements and functionality of the system. The researchers conducted and tested an experiment with the system if it can produce accurate result or output. The system was tested by monitoring the PH Level and temperature manually through LCD display and through mobile app of the user. If any problem occurred during the testing and operation, the researchers fixed the errors to achieve the outcome of the system.

Project evaluation

The System was evaluated using ISO 25010, International Standard of Evaluation software. ISO 25010 is an International Standard of Evaluation software. The fundamental objective of this standard is to address some of the well-known human biases that can adversely affect the delivery and perception of a software development project.

Solar Powered Vertical Hydroponic Farming using Internet of Things (IoT) was evaluated by the users based on the questionnaires provided.

III. RESULT AND DISCUSSION

This chapter presents and discusses the Solar Powered Vertical Hydroponic Farming using Internet of Things (IoT) and its evaluation results. This system was designed to create a prototype of Solar Powered Vertical Hydroponic Farming using Internet of Things (IoT) which could be run with a Solar Energy power source. The system has a hardware that is capable of automatic watering system and the adjustment of humidity and temperature of the Hydroponic Environment and the pH Level of the water tank of the Hydroponics. The system can help the farmer in Hydroponic System Innovation where the Hydroponics is powered using Solar Energy and the monitoring of the humidity, temperature and pH Level status is by the use of their android phones with the mobile app develop for the monitoring purposes of the Hydroponics System Sensors. The system software has a feature that shows the information or data reading of the sensors of the Hydroponics using Internet. The software is easy to use; the farmer should just click the Get Data Button to view the Sensor Reading and it has Data logs for the history of previous reading of sensor.

9.1 Develop a system that could help Hydroponic Farmer Monitor their Hydroponic Farm easily even in far location using mobile

phone and internet.

The first objective of the system was to develop a system that could help Hydroponic Farmer Monitor their Hydroponic Farm easily even in far location using mobile phone and internet. The android app can help the hydroponics farmers in an easy way of monitoring of the pH Level, humidity and temperature of hydroponics even in far location using android phone and internet.

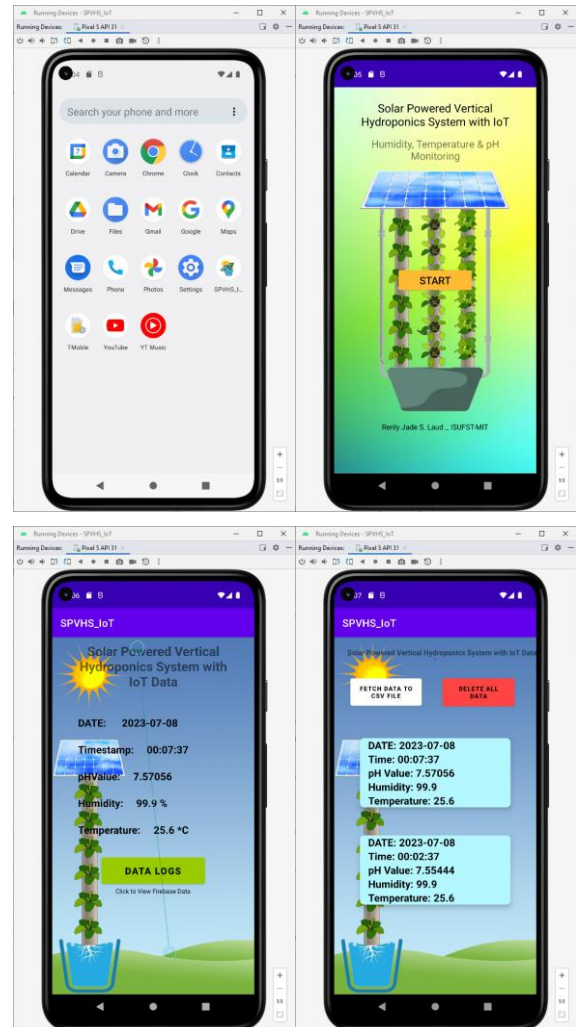


Figure 9.1.1 System's Mobile App User Interface. pH Level Humidity and Temperature monitoring

The Android App of the Solar powered vertical hydroponics system with IoT, pH Level, Humidity and Temperature Monitoring.

This software has features that display real-time database data of the sensors reading from hydroponics farm that is store in firebase database. By clicking the start button it goes to the new window where the latest data is displayed, and then by clicking the Data Logs it displays the History of previous sensor reading that is sort from latest to oldest.

Design a Vertical Type Smart Hydroponic garden with IoT.

Solar Powered Vertical Hydroponics System, The Hydroponics was designed in a vertical type and powered by a Solar Energy. It has DHT sensor that reads the humidity and temperature status and pH Sensor for pH Level processed by Arduino Wemos D1 hardware for monitoring. The system has an LCD Shield that displays the sensors data reading of the Hydroponics.



Fig. 9.3.1 Solar powered Vertical Hydroponics System

The second objective of the system is to design an incubator that could run by an AC/DC electrical power and to monitor the humidity and temperature inside the egg incubator using Arduino Uno hardware and sensors.

To develop a mobile application for pH Level, Humidity and Temperature Monitoring.

Firestore Database and Android Application Design

The system has a Firestore Realtime data where all the sensors data reading is stored then retrieved or fetch by the Android application that is developed using Android Studio. The Android Application is designed to get the data online on Firestore where the user/farmer can monitor the real-time sensor reading of its Hydroponic Farm. The Android App has also Data Logs of the previous sensor reading.

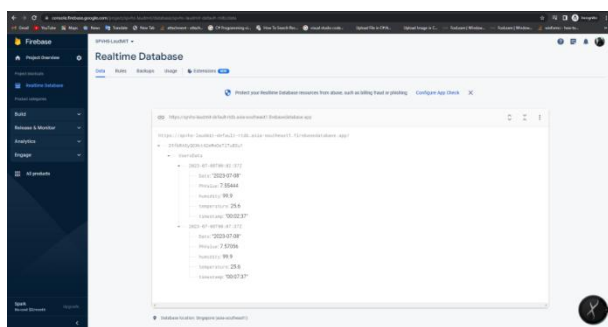
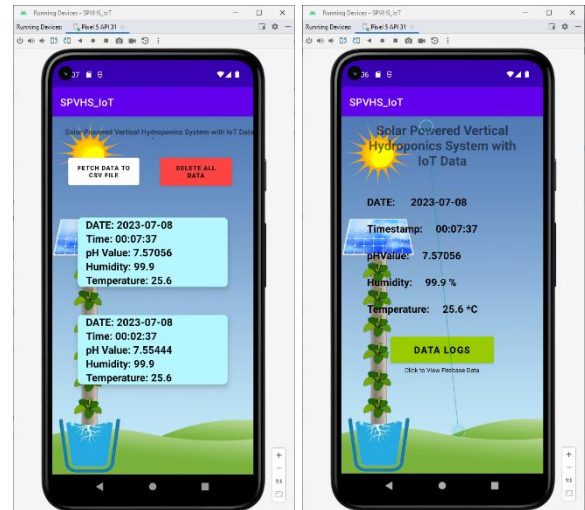


Figure 9.4.1. Hardware, software and IoT system design



9.5 Evaluate the system using ISO 25010 in terms of the systems characteristics: functionality, usability, efficiency, compatibility, maintainability, reliability, security and portability.

System Performance in Terms of Functionality

Functionality is a set of attributes that bear on the existence of a set of functions and their specified properties. The functions are those that satisfy stated or implied needs. Table 1 shows the result of the functionality of the System. The system got a grand mean of 3.87 or Very Good based on the evaluation of farmers and agriculture experts. In the four areas of Functionality, the system got the highest mean of 4.50 in Suitability and Accurateness from Agriculture Experts, while the lowest rating among the evaluators was the Interoperability from Agriculture experts also.

Table 1. Result of the Functionality of the System

Characteristic	Sub Characteristic	Farmers	Agriculture Experts	Grand total mean
		Mean Description	Mean Description	Mean Description
Functionality	Suitability	3.5 Good	4.5 Excellent	4 Very Good
	Accurateness	4.12 Very Good	4.5 Excellent	4.31 Very Good
	Interoperability	3.62 Good	3 Good	3.31 Good
	TOTAL Mean	3.75 Very Good	4 Very Good	3.87 Very Good

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In the four areas of Functionality, the system got the highest rating mean of 4.5 in Suitability and Accurateness from Agriculture Expert, while the lowest rating among the evaluators was the Interoperability from Agriculture expert also.

9.7 System Performance in Terms of Reliability

Table 2. Result of the Reliability of the System

Characteristic	Sub Characteristic	Farmers	Agriculture Experts	Grand total mean
		Mean Description	Mean Description	Mean Description
Reliability	Compatibility	4 Excellent	4.5 Excellent	4.25 Very Good
	Operability	4.5 Excellent	4.5 Excellent	4.5 Excellent
	Maturity	3.87 Very Good	4.5 Excellent	3.31 Good
	TOTAL Mean	3.75 Very Good	4 Very Good	3.87 Very Good

As shown in Table 2, in terms of reliability, the system was rated by farmers (M= 3.75) as very good and agricultural experts (M = 4.00) also as very good. The result showed that the system was reliable as a tool in terms of Ph Level, Humidity and Temperature monitoring using Internet of Things, that it gives a reliable and real-time data.

9.8 System Performance in Terms of Usability

Table 3. Result of the Usability of the System

Based on the evaluation of the Farmers and Agriculture experts, System was usable to the farmers in terms of monitoring using Internet of Things. The result showed that the system met the standard of the user for the pH Level, humidity and temperature monitoring Android app.

9.9 System Performance in Terms of Efficiency

Table 4. Result of the Efficiency of the System

Characteristic	Sub Characteristic	Farmers	Agriculture Experts	Grand total mean
		Mean Description	Mean Description	Mean Description
Efficiency	Time behavior	4.25 Very Good	4.5 Very Good	4.4 Very Good
	Resources Utilization	4.12 Very Good	4 Very Good	4.0 Very Good
	TOTAL Mean	4.2 Very Good	4.25 Very Good	4.22 Very Good

Table 4 shows the result of efficiency of the Solar Powered Vertical Hydroponics System with IoT. The result showed that the system was rated as very good with grand mean of 4.22 as a whole. Based on the evaluation of the farmers and agriculture experts, the system was efficient in terms of real-time data monitoring using mobile app through internet.

Characteristic	Sub Characteristic	Farmers	Agriculture Experts	Grand total mean
		Mean Description	Mean Description	Mean Description
Usability	Understandability	4.25 Very Good	4 Very Good	4.12 Very Good
	Learnability	4.12 Very Good	4.5 Excellent	4.31 Very Good
	Operability	4.25 Very Good	4 Very Good	4.25 Very Good
	Attractiveness	4.12 Very Good	5 Excellent	4.56 Excellent
	TOTAL Mean	4.2 Very Good	4.4 Very Good	4.31 Very Good

9.10 System Performance in Terms of Compatibility

Compatibility is the set of attributes that bear on the degree to which the system can exchange information to other components and performs their required function while sharing the same hardware or software environment.

Table 5. Result of the Compatibility of the System

Characteristic	Sub Characteristic	Farmers	Agriculture Experts	Grand total mean
		Mean Description	Mean Description	Mean Description
Compatibility	Co-existence	4.25 Very Good	4.5 Very Good	4.4 Very Good
	Interoperability	4.12 Very Good	4 Very Good	4.0 Very Good
	TOTAL Mean	4.2 Very Good	4.25 Very Good	4.22 Very Good

Table 5 shows the result of the Compatibility of the System where in it a Grand Mean of 4.22 or Good. In the two areas of compatibility, the system got the highest mean of 4.20 and 4.25 in co-existence, interoperability total of the mean. The result shows that the system is portable because it is working in Android phones once

installed and has Internet Connection.

9.11 System Performance in Terms of Maintainability

Table 6. Result of the Maintainability of the System

Characteristic	Sub Characteristic	Farmers	Agriculture Experts	Grand total mean
		Mean Description	Mean Description	Mean Description
Maintainability	Stability	3.62 Very Good	4 Very Good	3.81 Very Good
	Analysability	4.12 Very Good	4 Very Good	4.06 Very Good
	Testability	4.25 Very Good	4 Very Good	4.12 Very Good
	Changeability	4.12 Very Good	4 Very Good	4.06 Very Good
	TOTAL Mean	4.03 Very Good	4 Very Good	4.01 Very Good

Table 6 showed the result of Maintainability of the system. The system was rated as Very Good by the farmers with a mean of 4.03, and same also with agriculture experts with a mean of 4.00. The result showed that the system is maintainable based on the evaluation rating. The errors on system hardware and system software application can be diagnosed, modified and upgraded according to the use of the farmer.

9.12 System Performance in Terms of Security

Security is the set of attribute that bear on the degree to which the system protects or system has a degree of data access appropriate to their types and level of authorization.

Table 7. Result of the Security of the System

Characteristic	Sub Characteristic	Farmers	Agriculture Experts	Grand total mean
		Mean Description	Mean Description	Mean Description
Security	Accessibility	4.25 Very Good	4 Very Good	4.12 Very Good
	Confidentiality	4.12 Very Good	4 Very Good	4.06 Very Good
	Authenticity	4.25 Very Good	4 Very Good	4.12 Very Good
	TOTAL Mean	4.2 Very Good	4 Very Good	4.1 Very Good

Table 7 shows the result of the Security of the system. The system got the Grand Mean of 4.1 or equivalent to Very Good. In areas of Security the systems database is registered in the Google account of the user because it uses Google account to access the firebase database. Only the person that has access to the registered account could only open and manipulate the Firebase database.

9.13 System Performance in Terms of Portability

Table 8. Result of the Portability of the System

Characteristic	Sub Characteristic	Farmers	Agriculture Experts	Grand total mean
		Mean Description	Mean Description	Mean Description
Portability	Adaptability	3.62 Very Good	4 Very Good	3.81 Very Good
	Installability	3.78 Very Good	4 Very Good	3.89 Very Good
	Conformance	4 Very Good	5 Excellent	4.5 Very Good
	TOTAL Mean	3.80 Very Good	4.33 Very Good	4.06 Very Good

Table 8 shows the result of system portability. The farmers rated the system 3.80 or very good, while the agriculture experts rated the system 4.33 or very good also. The result showed that the system is portable because the user can use the monitoring app easily using internet.

Table 7. Result of the System Evaluation

Characteristics	Farmers	Agriculture Experts	Grand total mean
	Mean Description	Mean Description	Mean Description
Functionality	3.75 Very Good	4 Very Good	3.87 Very Good
Reliability	3.75 Very Good	4 Very Good	3.87 Very Good
Usability	4.20 Very Good	4.4 Very Good	4.31 Very Good
Efficiency	4.20 Very Good	4.25 Very Good	4.22 Very Good
Compatibility	4.20 Very Good	4.25 Very Good	4.22 Very Good
Maintainability	4.03 Very Good	4 Very Good	4.01 Very Good
Security	4.2 Very Good	4 Very Good	4.1 Very Good
Portability	3.80 Very Good	4.33 Very Good	4.06 Very Good
TOTAL Mean	4.01 Very Good	4.15 Very Good	4.08 Very Good

The system was rated as very good and the result of the evaluation met the main objective of the study develop a Vertical Hydroponic Farm with water level, PH level and humidity-temperature monitoring with automatic watering using IoT. The farmer can monitor the status of its Hydroponics Farm even in far locations using their Android phone and internet, even though the system had some limitations such as signal interruptions of internet. developing the system. The ISO 25010 standard quality model was used in the evaluation. These are functionality, usability, efficiency, compatibility, maintainability, reliability, security and portability.

The system was evaluated by only 30 respondents composed of 20 farmers and 10 Agriculture experts. The system got a grand total mean of “Very Good” as interpreted.

CONCLUSIONS

The researchers concluded that that the study is applicable in Hydroponic farming with Mobile application monitoring for the Ph level, humidity and temperature Hydroponic System. The system was capable of providing the farmers with an easy way of monitoring their Hydroponic farm Ph level, humidity and temperature status even if they are far from the farm as long as they had internet connection. The system is also eco-friendly due to it uses Solar Energy to Power up the Hardware of the system such as microcontrollers, motors, pumps and sensors.

RECOMMENDATION

In connection with the Hydroponics Farming, the researchers recommend using this system. It will surely help the farmers to grow crops in Vertical Type of Hydroponics System which is Solar Powered, Energy efficient and has a real time data monitoring in

Android Phone. The recommendation of the farmers and experts to the researchers is to upgrade this system in a large scale type for mass production of specific vegetable or plant that is planted in a hydroponic system. They also suggested putting an Electrical Conductivity Sensor that reads the nutrient content of the solution used and mix in hydroponic water.

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