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Computer vision-based color sorting machine for BPI Pn9 peanut (Arachis hypogea Linn.) kernel

John Christian C. Gealone[1], Wendy M. Cabarangao[2], Mia Krisha B. Maquera[3], and Dr. Jose D. Guzman

ABSTRACT

Peanut has been one of the major field legumes produced and is highly demanded by consumers in the Philippines due to its nutritional value. To ensure high quality peanuts in the market, sorting operations are done. Automated sorting can reduce human intervention and even maximize the yield of production. The primary objective of this study is to develop a prototype of a color sorter for BPI-Pn9 peanut kernels to ease the sorting method of the stakeholders. The detection of RGB values were carried out by a TCS3200 color sensor interfaced with an Arduino Nano microcontroller using a C++ library. The sorting method implies actuation by gate mechanism using DC servo motors which will separate the good quality peanuts from dark colored ones. The prototype was tested by comparing sorting accuracies obtained from four different speeds as represented by time delay in 5, 10, 15, and 20 milliseconds. When the speed of the motor is too fast or too slow, the accuracy may decrease. The peanut color sorter had an accuracy of 95.33% in an optimal speed by time delay of 15 milliseconds. Thus, proving its effectiveness in sorting peanut kernels accurately.

KEYWORDS

Keywords: peanut color sorter, computer vision, RGB values, sorting accuracy, peanut kernel

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1. INTRODUCTION

1.1. Background of the Study

In recent years, the demand for high-quality food products has surged, necessitating a stronger focus on automation and quality control measures. This trend is particularly pertinent in the case of peanuts, which are extensively utilized in the food industry. According to the Philippine National Standard/Bureau of Agriculture and Fisheries Standards 175:2015, sorting plays a crucial role in removing defective kernels from peanuts. The color-based sorting of peanuts is considered a vital step in the production process as it ensures the elimination of substandard or defective kernels, resulting in a consistent and superior final product.

Color sorting in agricultural products involves various methods, each with its own advantages and limitations. Optical sorting utilizes high-speed cameras and advanced image processing algorithms for accurate color-based sorting (Sankaran et al., 2010). This method offers high accuracy and non-contact sorting, making it suitable for a wide range of agricultural products. However, it can be costly and less effective for sorting products with similar colors or complex patterns. NIR spectroscopy, which utilizes near-infrared light, provides additional composition information alongside color analysis (Li et al., 2020). It operates at high speed but requires calibration and incurs setup costs. Manual sorting, reliant on human operators visually inspecting and sorting products, is cost-effective and flexible (Londhe et al., 2013). However, it is slower, prone to human error, and labor-intensive (Shravani et al., 2019).

Numerous research studies have investigated the use of computer vision algorithms for color-based sorting tasks, specifically the use of color sensors. Color sensors offer accurate detection and classification of color

properties, ensuring consistent sorting outcomes (Chauhan et al., 2021). They provide high speed and efficiency, enabling rapid sorting operations and increasing processing throughput (Batra et al., 2020). Being non-contact devices, they minimize physical damage to the products during sorting (Srivastava et al., 2020). Color sensors can be integrated into automated systems, allowing real-time monitoring and feedback for improved sorting accuracy (Tamboli et al., 2020). These advantages make color sensors highly suitable for use in the color sorting process for agricultural products.

1.2. Objectives of the Study

This study generally aims to develop a prototype of a color sorting machine for peanut kernels using computer vision. Specifically, it aims to determine the range of RGB color combinations for both good and dark colored peanut samples; the most efficient rotational speed of the motor upon feeding; and the right timing upon decision-making. The accuracy of the color sensor in terms of recognition and decision-making in either accepting or rejecting peanut kernels based on their RGB color range will also be determined. Lastly, the study will test whether there is a significant relationship between the motor speed represented by delay in milliseconds and its sorting accuracy.

1.3. Conceptual Framework

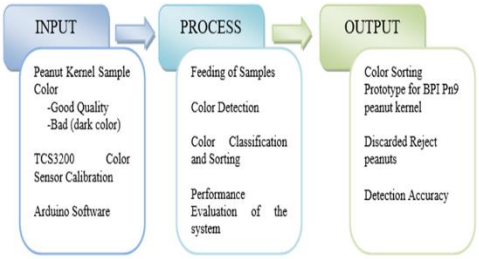


Figure 1-1. Conceptual framework of the study.

The pre-selected bulk of peanut kernel samples that are individually fed through the seed metering device is directed towards the detection area while being held during detection by a servo motor powered notched arm. The sample will drop towards the gate mechanism powered by another servo motor which receives the command from the Arduino to actuate by directing the samples to its respective bin, as per their classification.

An output from the sorting operation results in a discarded bad/dark color peanut kernels from the good quality ones with accuracy of sorting operation.

2. METHODOLOGY

Sample Preparation

BPI-Pn9 variety peanuts were obtained from Enrile, Cagayan. The total numbers of samples were 200 normal-sized kernels with 100 peanut kernels under good quality and another 100 under the classification of dark colored kernels. The peanuts were manually shelled, visually inspected and sorted. The good quality kernels have pinkish color while the bad ones are the discolored kernels/dark colors.

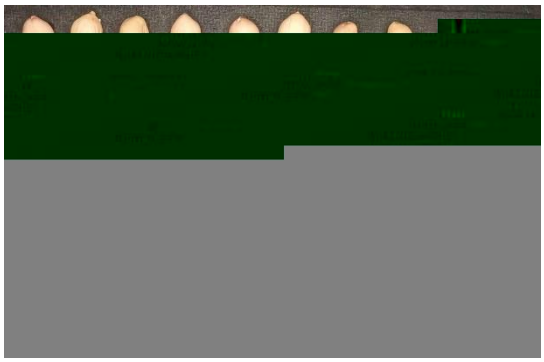


Figure 2-1. Image of good quality peanut kernel based on color.

Figure 2-2. Image of bad/reject peanut kernel based on color.

Figure 2-3 Illustrates the interconnection of the hardware components within the system and showcases the physical connections and relationships between the components, providing an overview of how they are linked together to form the operational system.

3. RESULTS AND DISCUSSION

This chapter presents the results of tests conducted with the integration of the H-PRO (Hybrid-Power Relay optimizer) into the existing PV (Photovoltaic) system to address and resolve the leakage issue. It further presents the background of the leakage problem, and the role of H-PRO in eliminating the leakage.

Hybrid – Power Relay Optimizer (H-PRO) is an innovative device designed to serve as an automatic switching device for Hybrid PV Systems. Its primary function is to prevent the leakage of current from the PV system to the grid by automatically disconnecting the connection between the PV system and the grid.

One of the key features of the H-PRO is its ability to monitor the voltage levels of the PV system. This monitoring is facilitated by utilizing an Arduino Uno microcontroller, which is programmed to continuously measure the voltage of the PV system. Based on the predefined voltage set point, the Arduino Uno is configured to automatically switch off the connection between the PV system and the grid when the voltage exceeds the set threshold.

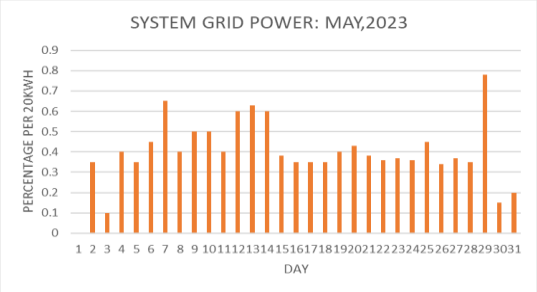
Its automatic switching capability, driven by the Arduino Uno's programmed logic, minimizes the need for manual intervention and ensures optimal operation of the PV system. The H-PRO combines advanced switching technology, voltage monitoring through the Arduino Uno, and automatic control mechanisms to effectively prevent current leakage and enhance the performance of hybrid PV systems.

Table 3-1 outlines voltage thresholds for the H-PRO system across varying battery system voltages. It automatically switches on at specific thresholds (12.5V, 24.5V, 36.5V, and 48.5V) and switches off at corresponding levels (13V, 25V, 37V, and 49V). This precise control optimizes solar energy utilization by activating grid power supplementation when solar voltage drops below the threshold. The narrow 0.5-volt difference efficiently harnesses solar energy, activating the grid when needed, reducing waste during low solar periods, and enhancing self-consumption. This grid reliance ensures uninterrupted power, meeting excess load needs, ultimately decreasing grid dependency and potential electricity costs.

	BATTERY SYSTEM VOLTAGE			
	12V	24V	36V	48V
On Threshold	12.5 V	24.5 V	36.5 V	48.5 V
Off Threshold	13 V	25 V	37 V	49 V

Table 3-1. Battery System Voltage Threshold

3.1. Hybrid Inverter Data



Total System Grid Power: 246 KWH

Figure 3-1. Daily System Load Power on the month of May 2023

Figure 3-1, illustrates the system grid power, expressed as a percentage, represents the proportion of the total power consumption supplied by the utility grid. The system grid power can be calculated by dividing the power consumed from the grid by the total power consumed. To determine the system grid power, it is necessary to ascertain the proportion of power obtained from the utility grid in relation to the total power consumption.

Without the H-PRO, there was a leakage power of 10.183333 Watt-hour was observed during a one-hour test, with an estimated

leakage power of 244.3999 Watt-hour for the day and 7.332 kWh for the month.

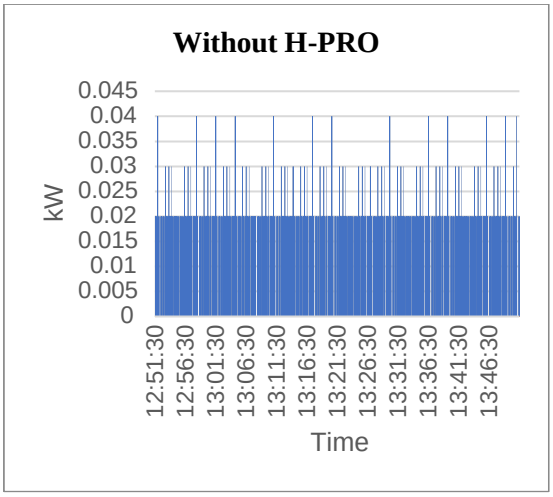


Figure 3-2. Without H-PRO

Figure 3-2 illustrates the graph a fluctuating or varying pattern of power leakage over time. It could exhibit irregular spikes or dips, indicating moments of increased or decreased leakage.

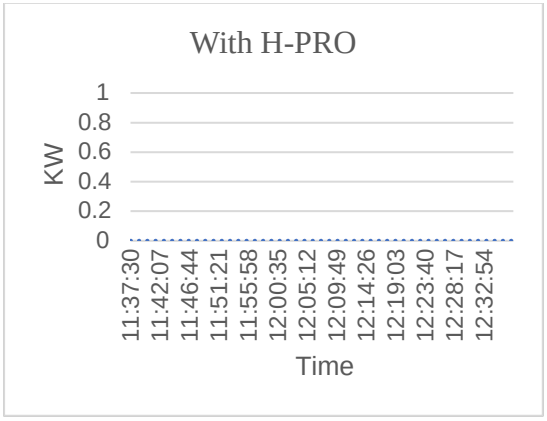


Figure 3-3. Power leakage for 1 hour

With the H-PRO in place, the battery level remained above 48.5 V throughout the entire duration of test, even with a load consumption of 1.76 kWh. The contactor remained off during this time, ensuring that no leakage power occurred.

Visualizing leakage currents on a graph can help in identifying patterns, anomalies, or trends that may require further investigation or mitigation measures to ensure the safety and efficiency of the electrical system. Leakage currents are typically very small, often measured in milliamperes (mA) or microamperes (μA). Therefore, it's crucial to use sensitive measuring instruments and ensure proper safety precautions are followed when working with electrical systems.

Additionally, if you suspect high or abnormal leakage currents, it's advisable to consult with a qualified electrician or professional to investigate and address any potential issues with the electrical system.

Table 3-2 shows the consumptions in the grid, load, and solar power.

May 2023				
Grid	Load	Solar Power	Leakage Power	Pesos / kWh
246 kWh	287.1 kWh	342.3 kWh	7.332 kWh	15.1783

Table 3-2. Data for Hybrid PV system of May 2023

Without the H-PRO, there was a leakage power of 10.183333 Watt-hour was observed during a one-hour test, with an estimated leakage power of 244.3999 Watt-hour for the day and 7.332 kWh for the month.

There is a 7.332 kWh power leakage which cost the consumer ₱113.7934 It is worthy to note that this leakage from the data collected the losses of the consumer is forecasted in Figure 3-2 and 3-3.

3.2. Electricity Bill Breakdown

Payment efficiency is an important measure that quantifies the effectiveness of reducing grid consumption by eliminating leakage. By comparing the grid consumption with and without leakage, we can determine the level of improvement achieved. A higher payment efficiency percentage indicates a more significant reduction in consumption.

To calculate the grid consumption, we use the formula: Grid Consumption = Grid power (kWh) x price/kWh + 5 Php/customer. This equation considers both the actual power consumed and the applicable price per unit, along with a fixed customer charge.

Table 3-3 provides a comprehensive breakdown of the On-grid bill, giving a detailed overview of the various components

that contribute to the total amount of 3580.26296 Php. It highlights the individual charges and taxes associated with the grid consumption.

For a thorough understanding of the specific charges related to leakage, refer to Table 3-4. This table presents an itemized breakdown of the Leakage Bill, including the charges and adjustments specific to leakage.

To obtain the grid consumption without leakage, we subtract the Leakage Bill from the total grid consumption. After eliminating the leakage, the resulting grid consumption is calculated as follows:

Grid Consumption (without leakage) = Grid consumption - Leakage

= 3580.26296 Php - 113.793484 Php

= 3466.4694 Php

For a more comprehensive analysis of the components contributing to the On-grid and Leakage Bills, please consult Table 3-3 and Table 3-4, respectively. These tables provide detailed information on each charge and adjustment, allowing for a deeper understanding of the billing breakdown.

Breakdown of the On-grid Bill				
Total KWH			246 KWH	
GEN/TRANS/SYS LOSS CHARGES				
Generation System Charge	9.2223	Php/kwh	2268.6858	Php
Generation VAT Charge	0.9862	Php/kwh	242.6052	Php
GRAM DAA Amount	0	Php/kwh	0	Php
GRAM DAA VAT Amount	0	Php/kwh	0	Php
ICERA DAA Amount	0	Php/kwh	0	Php
ICERA DAA VAT Amount	0	Php/kwh	0	Php
Transmission System Charge	0.6321	Php/kwh	155.4966	Php
Transmission VAT Charge	0.0761	Php/kwh	18.7206	Php
System Loss Charge	1.0958	Php/kwh	269.5668	Php
System Loss VAT Charge	0.1181	Php/kwh	29.0526	Php
	Sub Total		2984.1276	Php
DISTRIBUTION CHARGES				
Distribution System	0.5782	Php/kwh	142.2372	Php
Supply Retail charge	0	Php/cst	0	Php
Supply System Charge	0.6001	Php/kwh	147.6246	Php
Metering Retail Charge	5	Php/cst	5	Php
Metering System Charge	0.4326	Php/kwh	106.4196	Php
	Sub Total		401.2814	Php
OTHER CHARGES AND ADJUSTMENTS				
Lifeline (Disc/Subs)	0.0467	Php/kwh	11.4882	Php
Lifeline Rate Adjustment	0	Php/kwh	0	Php
Loan Condonation	0	Php/kwh	0	Php
Senior (Disc/Subs)	0.0004	Php/kwh	0.0984	Php
Senior Rate Adjustment	0	Php/kwh	0	Php
	Sub Total		11.5866	Php
UNIVERSAL CHARGES				
Missionary Elec. Charge	0.1783	Php/kwh	43.8618	Php
Environmental Charge	0	Php/kwh	0	Php
NPC Stranded Const Cost	0	Php/kwh	0	Php
NPC Stranded Debts	0.0428	Php/kwh	10.5288	Php
Cash Incentive - R. E. D.	0.0017	Php/kwh	0.4182	Php
Feed-In Tariff Allowance	0	Php/kwh	0	Php

Table 3-3. On-grid bill break down

Breakdown of the Leakage Bill				
Total KWH			7.332 KWH	
GEN/TRANS/SYS LOSS CHARGES				
Generation System Charge	9.2223	Php/kwh	67.6179036	Php
Generation VAT Charge	0.9862	Php/kwh	7.2308184	Php
GRAM DAA Amount	0	Php/kwh	0	Php
GRAM DAA VAT Amount	0	Php/kwh	0	Php
ICERA DAA Amount	0	Php/kwh	0	Php
ICERA DAA VAT Amount	0	Php/kwh	0	Php
Transmission System Charge	0.6321	Php/kwh	4.6345572	Php
Transmission VAT Charge	0.0761	Php/kwh	0.5579652	Php
System Loss Charge	1.0958	Php/kwh	8.0344056	Php
System Loss VAT Charge	0.1181	Php/kwh	0.8659092	Php
	Sub Total		88.9415592	Php
DISTRIBUTION CHARGES				
Distribution System	0.5782	Php/kwh	4.2393624	Php
Supply Retail charge	0	Php/cst	0	Php
Supply System Charge	0.6001	Php/kwh	4.3999332	Php
Metering Retail Charge	5	Php/cst	5	Php
Metering System Charge	0.4326	Php/kwh	3.1718232	Php
	Sub Total		16.8111188	Php
OTHER CHARGES AND ADJUSTMENTS				
Lifeline (Disc/Subs)	0.0467	Php/kwh	0.3424044	Php
Lifeline Rate Adjustment	0	Php/kwh	0	Php
Loan Condonation	0	Php/kwh	0	Php
Senior (Disc/Subs)	0.0004	Php/kwh	0.0029328	Php
Senior Rate Adjustment	0	Php/kwh	0	Php
	Sub Total		0.3453372	Php
UNIVERSAL CHARGES				
Missionary Elec. Charge	0.1783	Php/kwh	1.3072956	Php
Environmental Charge	0	Php/kwh	0	Php
NPC Stranded Const Cost	0	Php/kwh	0	Php
NPC Stranded Debts	0.0428	Php/kwh	0.3138096	Php
Cash Incentive - R. E. D.	0.0017	Php/kwh	0.0124644	Php
Feed-In Tariff Allowance	0	Php/kwh	0	Php

Table 3-4. leakage bill break down

3.3. Efficiency

To determine the percentage efficiency, we can use the following formula:

Formula	Calculation
Percentage Efficiency =	((Original Grid Consumption - Grid Consumption without Leakage) / Original Grid Consumption) x 100
Original Grid Consumption	₱3580.2629
Grid Consumption without Leakage	₱3466.4694
Substituting the values into the formula:	₱3580.2629 - ₱3466.4694)/ ₱3580.2629) x 100
Calculation:	(₱113.7934 / ₱3580.26296) x 100
Result:	3.1783%

Therefore, by eliminating the leakage, the grid consumption becomes more efficient, resulting in approximately 3.1783% reduction in payment compared to the original consumption.

3.4. Net Metering Vs. H-PRO

Net Metering Program

Process	Timeline	Cost Range
Distribution Impact Study	2 to 7 weeks	₱1,500 (ERC fee)
Yellow Card	2 to 4 weeks	-
Service Disconnect	2 to 7 weeks	₱8,000 to ₱24,000+
Electrical Permit Application	1 to 2 weeks	₱2,500 to ₱11,000+
Net Metering Application	2 to 6 weeks	-
Total Range	-	₱8,500 to ₱45,000

Table 3-5. Timeline and cost range of net metering program.

Table 3-5 provides an overview of the timeline and cost ranges associated with different processes involved in the application for net metering. Net metering allows individuals to generate their own electricity using renewable energy sources and feed any excess electricity back into the grid.

The total cost range for the net metering application, including the various processes mentioned, is estimated to be between ₱8,500 and ₱45,000+. It is important to note that these costs are approximate and may vary depending on factors such as location, specific requirements, and any additional expenses incurred during the application process.

H-PRO Component Costs

Component	Cost
Arduino Uno	₱546
Contactor	₱1,610
Synchronous rectification step-down module	₱219
Liquid Crystal Display I2C	₱149
Solid state relay with heatsink	₱582
Wires	₱297
Total cost of H-PRO materials	₱3,403

Table 3-6 Costs of the major Components of H-PRO

Table 3-6 breaks down individual costs for each H-PRO system component, providing a clear view of expenses. These approximations are subject to variation based on location, supplier, and market trends. Comparing with net metering, the H-PRO system stands as a notably more affordable choice. With a material cost of just ₱3,403, it offers an economical solution for curbing grid consumption. Even when contrasted with the lowest net metering cost estimate of Php 8,500, the H-PRO system remains the cost-effective option, given that net metering's highest cost is ₱45,000.

3.5. Return of Investment

To express ROI in years, we can use the Payback Period formula:

Payback Period = Cost of Investment / Annual Cash Flow)

Monthly Leakage = ₱113.7934

Annual Leakage = ₱1365.5208

	PRICE	PAYBACK
H-PRO	₱3,403	2.4921 years
NET METERIN	₱8,500	6.2247 years

Table 3-7 Payback period

Table 3-7 demonstrates the cost advantage of the H-PRO system over net metering. With a total material cost of ₱3,403+, significantly lower than net metering's range of ₱8,500 to ₱45,000+, the H-PRO system offers a more affordable option for reducing grid consumption. Furthermore, in terms of payback period or Return on Investment (ROI), the H-PRO system excels. It's payback period of under 2.4921 years surpasses net metering's estimated period of under 6.2247 years, showcasing superior financial feasibility and efficiency.

This data underscores the cost-effectiveness and advantages of the H-PRO system over net metering. With a shorter payback period and lower upfront costs, the H-PRO system appeals to individuals and businesses looking to enhance energy efficiency and reduce grid dependence, promising swift returns on investment and substantial long-term savings. In conclusion, the H-PRO system's affordability and shorter payback period make it a compelling choice for optimizing energy usage and cost-effectiveness, benefiting both individual users and businesses.

4. SUMMARY, CONCLUSION, AND RECOMMENDATIONS

4.1. Summary of Findings

In summary, the integration of the H-PRO into an existing PV system successfully resolved the leakage issue by automatically disconnecting the connection between the PV system and the grid. The H-PRO utilized advanced switching technology, voltage monitoring, and automatic control mechanisms to eliminate current leakage and improve the performance of hybrid PV systems.

Testing demonstrated that when the H-PRO switched off, the PV system was completely disconnected from the grid, effectively eliminating power leakage. Despite the presence of a current transformer, the existing PV system still experienced leakage, highlighting the limitations of the CT in addressing the issue. The H-PRO provided an

effective solution by detecting and eliminating leakage current.

Research findings is 7.332 kWh power leakage, resulting in a cost of ₱113.7934 to the consumer. By eliminating the leakage, the grid consumption became more efficient, leading to a reduction of approximately 3.1783% in payment compared to the original consumption.

The net metering program involves several processes, with associated costs ranging from approximately ₱8,500 to ₱45,000+. On the other hand, the H-PRO system incurred a total material cost of ₱3,403, offering a cost-effective alternative to net metering.

Overall, the integration of the H-PRO system provides an efficient solution for addressing leakage issues in PV systems, resulting in improved performance, reduced power leakage, and cost savings for consumers compared to traditional net metering programs.

4.2. Conclusions

In conclusion, the integration of the H-PRO (Hybrid-Power Relay optimizer) into an existing PV (Photovoltaic) system has proven to be a successful solution for addressing and resolving the issue of current leakage. By automatically disconnecting the connection between the PV system and the grid, the H-PRO effectively eliminates power leakage and enhances the overall performance of hybrid PV systems.

The H-PRO's utilization of advanced switching technology, voltage monitoring, and automatic control mechanisms ensures optimal operation and minimizes the need for manual intervention. Through comprehensive testing, it was demonstrated that when the H-PRO switched off, the PV system was completely disconnected from the grid, resulting in no power leakage.

The research findings revealed the limitations of the current transformer (CT) in addressing leakage issues in the existing PV system. However, the introduction of the H-PRO as a Hybrid-Power Relay optimizer effectively detected and eliminated leakage current, providing a reliable solution.

Furthermore, by eliminating the power leakage, the grid consumption became more efficient, leading to a reduction in payment of approximately 3.1783% compared to the original consumption. This highlights the H-PRO's ability to enhance energy utilization and contribute to cost savings for consumers.

In contrast to the traditional net metering programs, the H-PRO system offers a cost-effective alternative with lower expenses. The total material cost of the H-PRO was estimated at ₱3,403, making it an attractive option for reducing grid consumption and addressing leakage issues.

Overall, the integration of the H-PRO system presents a significant advancement in optimizing hybrid PV systems, ensuring their efficient operation, and reducing power leakage. It provides a practical and economical solution for consumers, offering enhanced performance, improved energy utilization, and cost savings. The H-PRO system demonstrates its potential to contribute to the sustainable development of renewable energy systems.

4.3. Recommendations

Based on the observations and the results collected during the testing, the researchers came up with the following recommendations:

1. Develop H-PRO as an IoT-based device for enhanced functionality and monitoring capabilities.
2. Use H-PRO to prevent rapid ATS source switching in PV systems with inverters, improving system stability.

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PV Module Efficiency Improvement Through Integration of Thermal Collector System

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ABSTRACT

Excessive use of nonrenewable energy sources resulted in increased pollution and climate change. At the same time, some challenges are faced when using a PV system. Its efficiency is not that high even in today's technology and even decreases due to high temperature. Another closely related system to PV systems is the thermal collector system. These two systems can be combined in one system. The study is being carried out to assess whether the combination of this system is more efficient. The system was designed after several trials on the individual combinations to determine the best configuration of the system. Furthermore, experiments were also conducted after assembling the whole system then compared to a regular solar panel. It was found that the system of the combined solar panel and thermal collector has better efficiency. Another test was also made through charging 12 volts 24.5Ah batteries to determine which can charge it faster. The PVT system's battery state of charge is 97.75% which is 1.36% higher compared to the PV system's battery state of charge which is 96.39%. The PVT system is 0.91°C lower in terms of temperature, it is 0.47% higher in terms of efficiency. If both solar panels efficiency, and cost were to be compared, the increase in efficiency is not able to sustain the increase in capital cost for the thermal collector. The PVT system's economic analysis shows that it will take a 9.99 years payback period considering the energy from the thermal collector. Thus, it is economically feasible

KEYWORDS

Photovoltaic and Thermal System, Thermostats, Solenoid Valve, Charge Controller

1. INTRODUCTION

1.1. Background of the Study

Everyone takes advantage of the many benefits that solar energy provides. It is non-polluting, renewable, and is available everywhere. It promotes economic growth by providing installation services. A solar photovoltaic system is a sort of solar energy technology that is fairly simple to maintain for the average household. Solar power plants are also more efficient and ecologically beneficial than conventional electric plants that generate gas.

However, studies show that efficiency of solar panels decreases when the cells' operating temperature increases because of solar intensity and ambient temperature. The Philippines receives primarily hot weather from March through May. The average temperature in the nation ranges from 25 degrees Celsius to 32 degrees Celsius (78-90° Fahrenheit), with an annual humidity of roughly 77 percent. Photovoltaic modules are tested at a temperature of 25 degrees Celsius (STC) - about 77 degrees Fahrenheit - depending on where they are placed.

This prompts the researchers to make a prototype design of a PVT system. In this system, the photovoltaic system will be integrated with the thermal collector system. The PVT collector or system is simply an integration of PV cells and a solar thermal collector in a single device, which should be able to convert solar energy into electrical and thermal energy simultaneously. However, this design is mainly to improve the overall efficiency of photovoltaic panels by reducing the temperature by adding thermal collectors using water as a medium for heat transfer.

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1.2. Objectives of the Study

Generally, the study aims to determine the feasibility of a solar - thermal integrated system for power generation.

Specifically, the study aims:

1. Determine the optimal arrangement of the combined system that improved the solar panel's efficiency
2. Compare a normal solar panel system and a solar/thermal integrated system in terms of electrical efficiency.
3. Calculate the economic aspect of the solar/thermal integrated system.

1.3. Conceptual Framework

Figure 1-1 shows the conceptual framework of the photovoltaic and thermal system (PVT). The main input of the system is mainly solar energy which provides radiant light and heat. Using photovoltaic and thermal systems, it will process the solar energy collected to produce electricity and heat energy for the water heating system.

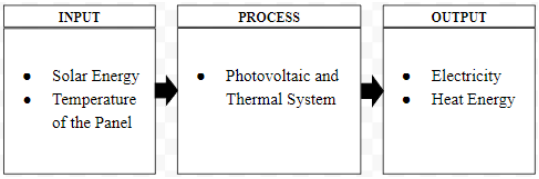

Figure 1-1. Conceptual framework of the study

2. METHODOLOGY

Solar panels efficiency is highly affected by temperature. As the temperature increases, the panel's efficiency decreases, and the quality degrades over time. The idea of a cooling system to balance the temperature of photovoltaic panels are introduced through the application of water based thermal collectors. Since these two systems are symbiotic to each other. The researchers proposed a study wherein these two separate systems merged to one system only.

In designing this project, the researchers provided different equipment needed in building the prototype of this project as shown in figure. Choosing the rights materials and equipment helps achieve the efficiency for the solar panel and to the water heating system the research is aimed for.

2.1. System Design

The main part of the system as shown in figure 2-1 is the combined photovoltaic panel and thermal collector

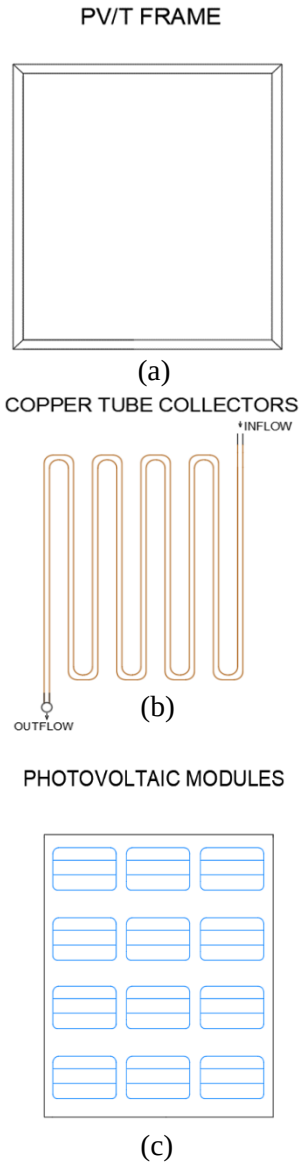

Figure 3-1. (a) PVT frame; (b) collector tubes; (c) photovoltaic module

Using a wooden frame with insulation inside of it, the tube copper collectors assembled in the frame. These tubes serve as the way out for the water when absorbing the heat collected. Next is the photovoltaic module which is assembled on top of the thermal collector and then enclosed by a cover glass.

As shown in figure 2-2, the photovoltaic and thermal systems serve as the cornerstone of PVT systems and are crucial for absorbing heat from PV panels and converting it to thermal energy. It can be either an active or passive system but, in this project, the researchers use a passive system by means of natural flow of water or gravity. The heat from the panel is absorbed by the water turning the water into warmth. As the water reaches its set temperature, the thermostat opens the passageway of the warmed water going to the insulated water tank. On the other hand, the electricity converted by the PV is stored in batteries which are used as source ac loads.

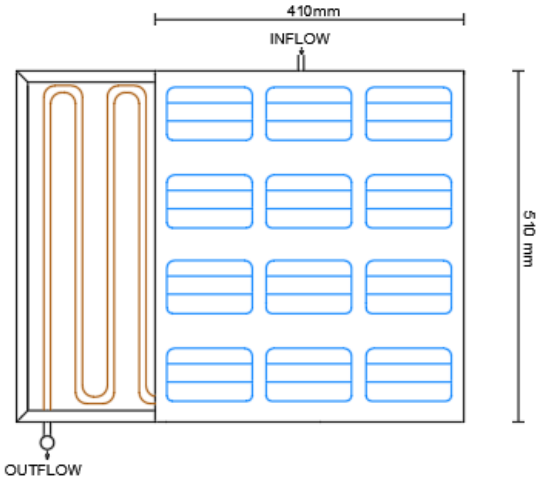

Figure 2-2. Combined Photovoltaic Module and Thermal Collector

Figure 2-3 shows the arrangement of the combined system that achieves the goal which is to improve the efficiency of the solar panel.

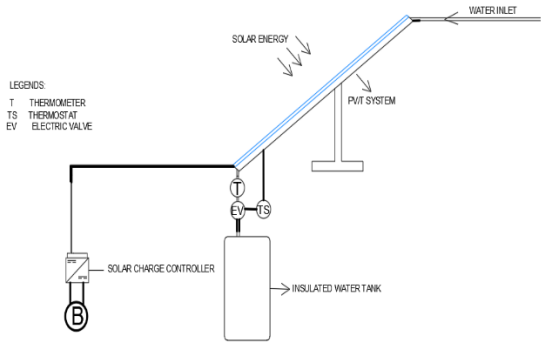

Figure 3-3. PVT System

2.2. System Components

Adapter - is a specific device used to connect electrical equipment to a power supply or to link many pieces of electrical or electronic equipment together.

Batteries - energy storage devices that release stored energy by turning chemical energy into electricity.

Charge controller - voltage and/or current regulator to prevent overcharging of batteries. It controls the voltage and current from the solar panels to the battery.

Copper tubes - most common application is for heating systems and as a refrigerant line in HVAC systems. PEX tubing is gradually replacing copper tubing in hot and cold water applications.

Insulated water tank - minimizes the amount of heat lost or gained, maintaining stored liquids at a steady temperature while consuming the least amount of energy.

Inverter - a power electronic device or circuitry that converts direct current (DC) to alternating current (AC) The resultant AC frequency is determined by the device used.

Solar panel - an assemblage of photovoltaic solar cells installed in frame, as well as a nicely ordered collection of PV panels. Solar panels collect radiant energy from the sun and convert it to direct current (DC) power.

Solenoid valve - a valve that is operated by electricity. A solenoid, which is an electric coil with a moveable ferromagnetic core (plunger) in its middle, is used in the valve.

Thermostat - a gadget that automatically adjusts temperature or activates a device when it reaches a specified temperature.

2.3. System Block Diagram

Although the foundations of solar thermal technology are straightforward, building a system that successfully collects solar energy and transforms it to warm water necessitates the use of technology. The installation of solar panels is the first stage in converting solar energy into a usable resource. The

Photovoltaic and Thermal system function by absorbing solar radiation through collectors on the panel. Then the energy causes the water to become warm which flows around a sealed circuit, through the collectors, and into inside an insulated water tank. After that, the warm water is kept in the tank until it is required.

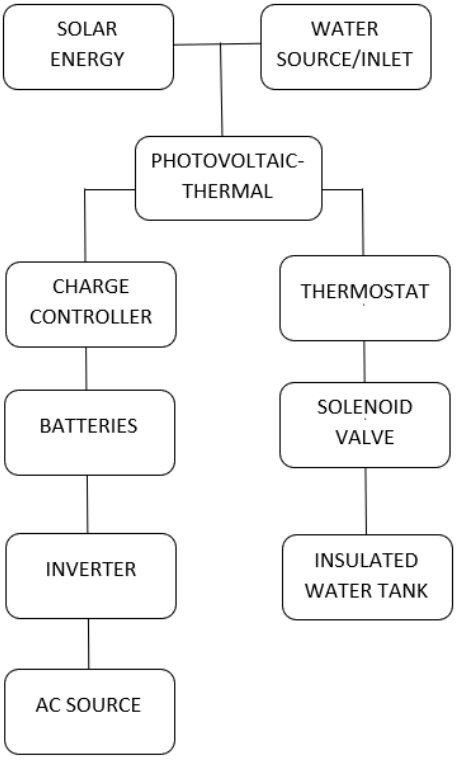

Figure 2-4. Block diagram of the photovoltaic-thermal system

2.4. System Calculations

2.4.1. Electrical Efficiency

It is now feasible to create electricity by converting solar energy into electricity. This technique is known as "photovoltaic" (PV).

Photovoltaic technology is based on the usage of cells containing photovoltaic materials, known as solar cells, which are in charge of receiving and converting solar radiation into electric power.

The electrical efficiency is computed using the incoming solar radiation and the temperature of the PV module utilized in the tested PVT collectors using the formula:

$$\eta_{ee} = \frac{I_{SC} * V_{OC} * FF}{Apv * E}$$

Where:

- η_{ee} *is the electrical efficiency*
- I_{SC} *is the current* (A)
- V_{OC} *is the cell voltage* (V)
- FF *is the fill factor*
- Apv *is the area of the photovoltaic panel*
- E *is the irradiance from the sun*

In this situation, the PV module must be at a lower working temperature under specified parameters of incoming solar radiation intensity, ambient air temperature, and wind speed to optimum electrical production.

2.4.2. Energy Stored in the Battery

The produced energy in kWh of the photovoltaic system is to be stored on a battery and is calculated using the formula:

$$P = \frac{\Delta\ State\ of\ Charge * battery\ Ah * battery\ voltage}{1000}$$

Where:

- P is the energy stored by the PV System (kWh)
- Δ State of charge is the change in the level of charge of the battery in percentage (see table: Appendix Table 22. State of Charge)
- battery Ah is the rated current hour of the battery.
- battery voltage is the nominal battery voltage (12.7V)

2.4.3. Energy Produced by the Thermal Collector

The energy generated by the solar system's thermal collector, in kWh, is determined by the change in temperature and the amount of water to be heated, and is calculated using the formula:

$$Q = m * C * \Delta T$$

Where:

- Q is the quantity of heat required to raise the temperature of water (kWh)
- m is the mass of water
- C is the specific heat capacity of water (1.16*10^(-3) kWh)
- ΔT is the change in temperature (K)

2.4.4. Total Energy Output of the System

PVT modules are more productive than side by side PV panels and solar thermal collectors because they can generate more energy per unit surface area. The results for PVT energy production may be achieved by adding the

energy stored by both the solar system and the thermal collector or hybrid system.

$$E_{total} = (P + Q) - Consumption$$

3. RESULTS AND DISCUSSION

Data were obtained using different experimentation on the test runs of the converted tricycles. After further computations, the comparison between the performances and economic side of the converted tricycles will be determined.

3.1. Optimal PVT System Design

The researchers conducted several experiments while designing the system to determine the best material and configuration to use for the photovoltaic/thermal (PVT) system for maximum output.

The researchers tested a closed system of different material design. Design 1 is the photovoltaic/thermal system where the thermal collectors are not directly in contact with the solar panel and behind the panel is an insulated closed system. The total volume of water the copper tubes can contain is 280 ml. A clearance of 30mm between the back of the solar panel to the collector tubes. Insulation was also put beneath the copper tubes.

Design 2 is a system that is the same with design 1 but with a transparent glass in between the panel's back and the copper tubes.

Design 3 is a system where the thermal collectors are directly in contact with the solar panel and behind the panel is an insulated closed system. The total volume of water the copper tubes can contain is increased to 450 ml due to the addition of copper tubes.

Lastly, the system is almost similar with the third setup, but the only difference is that the insulation behind the panel is removed.

The researchers compared each PVT design panel's surface temperature to the control variable which is the photovoltaic system alone. Panel's surface temperature was the basis for choosing the optimal configuration since it is stated that the higher the temperature, the lower the efficiency and output. Thus, the PVT configuration with the lowest temperature was chosen as the optimal setup of the photovoltaic/thermal system.

Table 3-1 shows the data gathered regarding the panel's surface temperature of each PVT design being compared to the PV system's panel's surface temperature. It is evident that design 4 or the design wherein the thermal collector is directly in contact with the panel's back in a closed system without insulation has the lowest difference of the average of temperature which is -0.88. The lesser the difference of the average temperature the better the efficiency of the PVT system. Therefore design 4 has the highest efficiency among all the PVT systems because the difference of the average of temperature is the lowest.

Considering the results, the researchers selected design 4 as the optimal design. This design has the thermal collectors directly in contact with the panel's back in a closed system. When design 4 is compared to the PV system it has a lower average temperature, thus considered as more efficient.

3.2. Electrical Efficiency and Panel Temperature

Researchers built the system according to the chosen materials from the initial experiment. After the fabrication of the PVT system, the researchers conducted an experiment to compare the electrical efficiency and panel temperature of the PVT and the PV system. The data needed for the efficiency calculation and panel temperature were gathered for four (4) weeks and each day were monitored from 9:00 AM to 3:00 PM with a 30-minute interval. Figure 3-1 and Figure 3-2 shows the result of the data gathering and testing.

As shown in Figure 3-1 the average daily efficiency of the solar/thermal (PVT) system is greater compared to the average daily efficiency of the photovoltaic system. Averaging the data above for each system, the PVT system has an average efficiency of 10.79% while the PV system has an average efficiency of 10.32%.

Table 3-1. Comparison of the different PVT design's panel surface temperature (°C)

Time	Surface Temperature of the Designs and Panel (degrees Celsius)									Ave.	Ave. Difference
	10:00	10:30	11:00	11:30	12:00	12:30	1:00	1:30	2:00		
Design A	36.7	39.5	40	41.9	43	43.5	42.6	39.7	38.5	40.6	1.9
PV system	36	38.5	38.9	39.5	40.1	41.5	39.4	37.5	37	38.7	
Design B	30.9	35.5	36.3	37.5	41.8	42.5	41.8	40.8	38.8	38.4	1.4
PV system	30.8	34.2	34.9	36.7	39.2	40.4	39.7	39.2	37.8	37	
Design C	33	34	38.9	39.5	40.5	41.3	40.5	41	37.1	38.4	0.6
PV system	32.9	33.2	37.9	38.6	39.5	40.2	40.6	40.9	37.1	37.8	
Design D	31.4	33.2	34.6	36.5	38.9	39.1	38.3	37.1	35.8	36.1	-0.7
PV system	31.9	33.8	36.1	37.8	39.2	40.4	39.7	37.9	36	36.8	

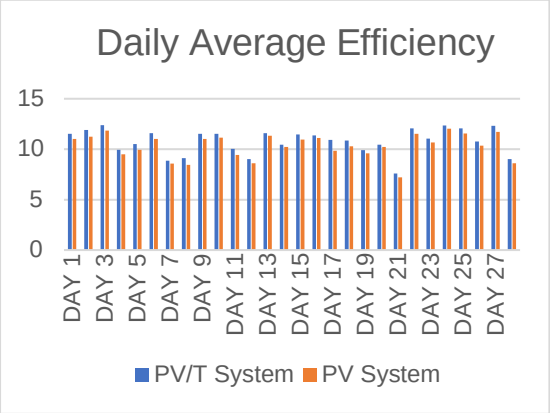

Figure 3-1. Average Efficiency of the PVT and PV System (%)

This shows that the PVT system can reach an efficiency closer to the maximum efficiency of the panel which is 14.35%.

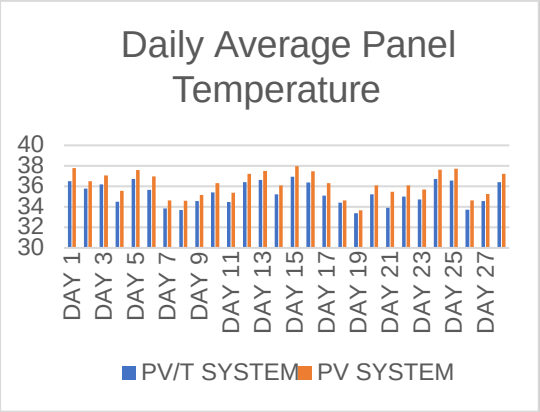

Figure 3-2. Average Daily Temperature on the Surface of the Panel (°C)

As shown in Figure 3-2 the average daily temperature of the solar/thermal (PVT) system's panel is lesser compared to the average daily temperature of the photovoltaic system's panel. Thus, proving the effectiveness of the thermal collector when it comes to absorbing the heat from the solar panel.

The data gathered indicates that the lower the temperature on the surface of the panel the higher the efficiency of the system, as we can refer from the graph of the data gathered for the PVT system when compared to the PV system. On the other hand, the higher the temperature on the surface of the panel to lower the efficiency of the system, as we can refer from the data gathered for the PV system when compared to the PVT system.

3.3. Energy Stored in Batteries

The researchers conducted an experiment to determine the output of the PVT system when it comes to charging a battery compared to the output of the PV system. The experiment was conducted for 28 days or 4 weeks. Table 3-2 shows the results of the investigation. The results show that the PVT system has a greater energy output compared to the PV system when it comes to battery charging. This also indicates that the PVT system can charge a battery faster compared to the PV system.

Week	Energy Stored in the Battery	
	PVT System	PV System
1	1.008126	0.983234
2	1.014349	0.99568
3	1.014349	0.9987915
4	1.0112375	0.99568
Sum	4.0480615	3.9733855

Table 3-2. Energy Stored in the Batteries (24.5Ah per system)

3.4. Energy Produced by the Thermal Collector

The energy produced by the thermal collectors depends on the initial temperature of the water, the final temperature being set on the thermostat, and the total volume of water being heated. The total volume of water depends on how many times the solenoid valve opened and released the heated water and the amount of water the collector can contain. The design used for the data gathering can contain a total of 450 ml of water. 1 liter of water is equivalent to 1 kilogram. Table 3-3 shows the result of the data gathering.

Week	Volume of Water (Kg)	Energy Produced by Thermal Collectors (KWH)
1	56.25	0.800226
2	60.75	0.8531568
3	54.9	0.7820082
4	63.9	0.8665722
Sum	235.8	3.3019632

Table 3-3. Energy Produced by the Thermal Collector (kWh)

3.5. Total Energy Output of the System

The PVT system consists of a thermostat that is used to sense the desired water temperature in the thermal collector before being released by the solenoid valve. Such devices consume electricity to operate. The data for the power consumption for the PVT system is shown in the table below. The power consumption of the system was measured by their operating time. The thermostat operates for five hours with an ampere rating of 0.02A. The solenoid valve ampere rating is 1.85A. It operates dependently with the thermostat and the time it was triggered was recorded. Table 4-4 shows the power consumption of the system on a weekly basis.

Week	Current Rating(A)		Operating Time (hour)		Consumption (kWh)
	Thermostat	Solenoid Valve	Thermostat	Solenoid Valve	
1	0.14	12.95	35	0.39	0.0171
2	0.14	12.95	35	0.4139	0.0176
3	0.14	12.95	35	0.3733	0.0167
4	0.14	12.95	35	0.4308	0.0180
Sum	0.56	51.8	140	1.6081	0.0693

Table 3-4. PVT System Power Consumption (kWh)

Table 3-4 shows the power consumption of the thermostat and solenoid valve. The results show that the thermostat total operating hours were 140 and 1.608055556 for the electric solenoid valve. Considering the ampere rating of the devices, the total power consumption for 28 days was 0.069298833 kWh.

Subtracting the power consumption of the thermostat and the solenoid valve to the sum of the energy stored in the battery constitutes the total energy output by the PVT system. Data gathered were shown in Table 3-5.

Week	PVT System (kWh)			PV System (kWh)
	Energy Stored at Battery	Power Consumption	Total Energy	Total Energy
1	0.9702	0.0171	0.9531	0.94668
2	0.94962	0.0176	0.9320	0.92022
3	0.91728	0.0167	0.9006	0.89082
4	0.93786	0.0180	0.9199	0.90552
Sum	3.77496	0.0693	3.7057	3.66324

Table 3-5. Total Energy Output (kWh)

Table 3-5 shows the data gathered for the PVT system including the PV system alone. The results show that the total output of the PVT system, which is 3.7057 kWh, is more than the output of the PV system which is 3.6632 kWh having a difference of 0.425 kWh. This indicates that the integrated photovoltaic and thermal collector system did not just increase the efficiency of the solar panel but also increase the total energy output or the total

energy to be saved when installing the system for household use.

3.6. Economic Analysis

Economic analysis is conducted for the study to determine the payback period, or simply the time required to recover the project's initial costs. The result is compared to the average life of the system. This is used to evaluate whether the project is economically feasible or not. This section presents the system's economic analysis.

3.7. Optimal Time to Use Solar Panel

The result of the experiment was on a four weeks or 28 days basis considering good weather conditions with an ambient temperature of not less than 29°C.

The average annual temperature for Apayao is 30° degrees. The highest average temperature is 34°C in June and the lowest is 25°C in January. April to September are the months with the hottest temperature in the region, averaging 32.5°C (besttimetovisit.com.ph).

If the system is to be installed in Apayao, there is a total of approximately twenty-six weeks (26) or 182 days (April to September) for solar panels to be optimally beneficial. Therefore, in calculating the economic aspect the researchers considered 26 weeks for the PVT system to be utilized in consideration to the location and climate of the region the system is to be installed, which is in Apayao province.

3.8. Investment Cost

Components	Qty. Units	Unit Price	Total
3230 Thermostat	1 pc.	₱160	₱160
2V Solenoid Valve	1 pc.	₱550	₱550
Copper Tubes	8 pcs.	₱200	₱2400
Copper Elbows	12 pcs.	₱35	₱420
Wire conductor	1 m	₱25	₱50
Charge Controller	1 pc.	₱180	₱180
Battery	3 pc.	₱400	₱1200
Solar Panel	1 pc.	₱1199	₱1199
Sealant	1 pc.	₱70	₱70
TOTAL			₱6229

Table 3-6. PVT System Bill of Materials

3.9. Measure of Profitability Investment

According to National Renewable Energy Laboratory (NREL) data, solar panels have a degradation rate of roughly 0.5% per year. So, after 20 years of use, a solar panel would be capable of producing roughly 90% of the electricity it produced when it was new. Based on that information, solar panel manufacturers typically offer warranties of about 25 years or more. And in the case of newer or well-built systems, panels can last for 30 years. Thus, solar panels usually last for 20 to 30 years (Gobler, 2021)

Material Cost: ---------- ₱6229.00
Cost per Kilowatt-Hour: --------- ₱13.68

$$\text{9AAG1HQUPQP} = \frac{\text{6KP1eQIPLQP}}{\text{0QI>AKNB9AAGKOBx=P)=IPANEJC}}$$

$$\text{9AAG1HQUPLIQP} = \frac{\text{yätryxG9D}}{\text{v9AAGO}}$$

$$\text{9AAG1HQUPLIQsäywsfG9D9AAG}$$

Annual Income:

$$\text{\#JJQ=HI?KIA} = \text{LIsäywsf}\frac{\text{G9D}}{\text{9AAG}}$$

$$\text{Ût x 9AAGpÛ:} = \frac{\text{–sueäxz}}{\text{G9D}};$$

$$\text{\#JJQ=HI?KILA–xtüst}$$

Return on Investment:

$$\text{41+L}\frac{\text{\#JJQ=HI?KIA}}{\text{+JRAOP?AKJDPP}}$$

$$\text{41+L}\frac{\text{–xtüst}}{\text{–xtt{}}}$$

$$\text{41+L rüs}$$

Payback Period:

$$\text{Payback Period} = \frac{\text{Cost of System}}{\text{Annual Savings}} + \text{Years}$$

$$\text{Payback Period} = \frac{\text{Cost of System}}{\text{Annual Savings}}$$

$$\text{Payback Period} = \text{Years}$$

Based on the calculation the researchers concluded that the efficiency and total energy output of the solar – thermal integrated system (PVT) is increased; also, the PVT system is economically feasible.

4. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

4.1. Summary of Findings

This research is conducted to improve the efficiency of solar panels by integrating it with thermal collectors (PVT system). The PVT system design chosen was the design where the thermal collectors are directly in contact with the solar panel without an insulation since it has the lowest average difference of -0.7 when compared to a PV system. The data gathered for the panel's surface temperature shows that the PVT system has a lower panel's surface average temperature of 35.31°C compared to the PV system panel's surface average temperature which is 36.22°C. In terms of efficiency, the PVT system's efficiency is higher, which is 10.79% compared to the PV system's efficiency which is 10.32%. It is evident that the PVT system is 0.91°C lower in terms of temperature and it is 0.47% higher when it comes to efficiency. The economic analysis of the PVT system shows that it will take 9.99 years to recover the capital cost of the system which is lower than the lifespan of solar panels which is 20 to 30 years. Thus, the PVT system is economically feasible.

4.2. Conclusion

It was found out that the PVT system has a lower panel's surface temperature and higher efficiency compared to the PV system. Furthermore, the PVT system can charge a 12-Volt, 9Ah battery faster compared to the PV system. Lastly, it was found out that the total energy output of the PVT system is more than twice the output of the PV system. Thus, looking at its economic analysis, it would take approximately ten (10) years to recover the initial cost which is half of the maximum economic life of the system. Therefore, it is concluded that a PVT system improves the efficiency of solar panels and at the same time provides greater energy output, and this system is economically feasible.

4.3. Recommendations

The researchers would like to recommend the following for the improvement of the study:

1. Use a battery with larger capacity to utilize solar energy to be stored by a solar panel for 8 hours a day.
2. Try to use copper tubes of larger diameters to increase the volume of water for the thermal collector.
3. Use thinner solar panels to dissipate heat easily.
4. Apply in bigger panels to identify the differences.
5. Use another type of thermal collector.
6. Longer time of testing.
7. Gather data during summer season on which temperature spikes

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Iot- Based Automated Hydroponic Nutrient Solution Management System

Mike Jay-vee P. Almonte[1], Melisa B. Biraquit[2], John Paul L. Galache[3], Arielle Gemae Javier[4], and Engr. Lawrence Jay M. Nunag[5]

ABSTRACT

The IoT-Based Automated Hydroponic Nutrient Solution Management System is designed to alter and improve the traditional hydroponic system in order to use it safely and productively, as defined by its unique operational requirements. The sensors were electronically incorporated into the system that continuously checks and corrects the TDS and pH values of the nutrient solution, and it also has an automated mixer. The system reduces the amount of human interaction, which eliminates human error while keeping costs to a minimum and ensuring maximum yield. The operation of the system, which consists of reservoirs, pH solutions, and nutrient solutions, as well as the necessary pH sensor, TDS sensor, ultrasonic sensor, water temperature sensor, buzzer, servo motor for the mixer, peristaltic pumps, and water pumps, is discussed in this article. Sensors were installed in the reservoir to monitor operational conditions and the need for checking water level, pH monitoring and control, TDS monitoring and control, and automated mixing.

KEYWORDS

TDS, pH, automated mixer

1. INTRODUCTION

1.1. Background of the Study

One of the sustainable food production techniques that works with natural laws and seeks to improve rather than exploit natural living systems is hydroponics, a true marvel of contemporary technology. With hydroponics, vital nutrients are delivered right to the tips of the roots of the plants, simulating their basic natural environment. An alternate approach for growing plants that do not utilize soil is called hydroponics, which originally referred to nutrient solution cultivation.

Numerous research supports the benefits of using hydroponics. However, hydroponics necessitates regular monitoring of the TDS (total dissolved solids) and pH (potential hydrogen-hydroxyl) levels. To regulate the operation of the system and to keep an eye on the quality of the nutrient solution the plant needs, the system detailed in this article integrates current developments in the electronics sector with the burgeoning automation technologies. This will reduce human involvement and reduce, if not completely eliminate, human error for the lowest cost and maximum return.

At the moment, it is evident that the rising urbanization is placing stress on land resources. In the Philippines, there is a strain on land use and natural resources due to the country's need for food production. According to estimates, 6.8 hectares of forestlands lose 400,000 hectares annually, contributing to the degradation of the forestland alone. Food production is cited as the root cause of this damage (Gabriel A.G., 2017). Furthermore, according to the Philippine Statistics Authority (PSA), the Philippine population is expected to grow from 93 million in 2010 to 142 million in 2045.

A decrease in agricultural production as a result of the nation's rapid urbanization, the deteriorating irrigation situation, and the tragedy associated with natural disasters are just a few indicators that point to the need for the agricultural sector to be less reliant on traditional farming methods (PSA, 2016). If local government entities do not adjust to

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these realities, the anticipated increase in urbanization and population expansion may make urban residents even more susceptible to unforeseen shocks in agricultural markets (Matuschke I, 2016). The United Nations (UN) predicted that by 2050, there will be around 10 billion people on the planet, increasing the demand for food production. While contemporary industrialized agriculture can provide the demand for food, it also continuously depletes topsoil and aquifers and pollutes air and water due to its reliance on pesticides and other agrochemicals. In addition, severe food shortages are a result of climate-related calamities such flooding, unreliable rain, droughts, and extreme heat. It doesn't help that the Philippines' geographic location in the western Pacific Ocean and proximity to naturally warm seas make it prone to extreme weather. As a result, the nation is ranked as the one most impacted by climate change in 2015 by the Global Climate Risk Index. This poses a threat to the nation's agricultural industry and will likely result in material reductions in food production (Lagomarsino V, 2019).

The adoption of alternate systems, such hydroponics, which can grow food in a controlled environment, with less water, and in higher yields, is necessary for the aforementioned reasons. Future food security is a challenge that requires a lot of technology to solve. Studies demonstrate the various advantages of hydroponic gardening over traditional soil farming. Delivering precise amounts of nutrients at specific timings, hydroponics effectively mimics the essential components of a plant's natural environment (Robbins O, 2021). Hydroponics, however, necessitates regular monitoring of the pH and TDS (electrical conductivity) values.

Current hydroponic technology is applied in a traditional manner in the Philippines. There has previously been research that improved our grasp of hydroponic technology, and it is obvious that experts are aware of the many benefits of hydroponic plant growth over soil-based plant growth. Farmers have already made attempts to use a hydroponics system, but these efforts have either been abandoned or have not found favor with the local farmers. Some growers and farmers struggle with the issue of controlling the TDS value. They are not prepared for the calculations of the precise dosage of fertilizers designed especially for hydroponic plants. The precise formulation should be examined to allow an estimation of the amounts of nutrient solution to be added, and the level of TDS and the pH values of the resulting nutrient solution should be monitored. This is a crucial part of hydroponic techniques. Therefore, the main things that prevent the technology from being stable are the farmers' technical expertise and the right support to maintain the chemicals for nutritional formulation. According to the common farmers' worries, hydroponic farming is a more involved and complicated method than earth farming. In order to diminish human involvement in monitoring and maintaining the pH level and TDS of the nutrient solution that is appropriate for the plants' life requirements, this project was carried out. Its goal is to concentrate on plant growth as well as come up with a solution that would reduce human involvement in the maintenance of the nutrient solution.

The secret to effective hydroponic gardening is the management of the nutrient solution. Correct pH, nutrient concentrations, and ratios in the solution all affect how readily available elements are to plants (Lincoln and Eduardo 1972). The potential hydrogen-hydroxyl ion content of a solution is described by the word pH. Positive and negative ions form when solutions ionize. For instance, using highly soluble nutrients of the highest purity possible for lettuce at a pH level between 5.6 and 6.0 will yield the best results. Salts that have been dissolved in water are used as nutrients. The TDS, a characteristic that affects a plant's capacity to absorb water, is an important metric to assess the amount of salt or salts in solution. The decrease in electrical conductivity, which may be used to monitor the concentrations of nutrients in the solution,

is connected to a drop in salt concentration at a constant water level (Junior C.H, 2008).

1.2. Objectives of the Study

The study aims to provide an IoT- based Automated Hydroponic Nutrient Solution Management System to hydroponics systems at Carig Sur, Tuguegarao City and Iguig, Cagayan.

Specifically, the study aims to:

1. To manually calibrate the sensor used for measuring pH.
2. To develop an IoT-Based Automated Hydroponic Nutrient Solution Management System that automatically corrects the required pH and TDS with an automated mixer.
3. To develop a webpage that monitors the system's real-time sensor data.

1.3. Conceptual Framework

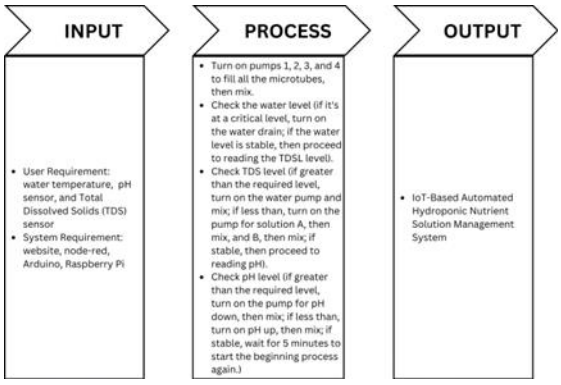

Figure 1-1. Conceptual Framework for the System

2. METHODOLOGY

2.1. Research Design

This study used an experimental research method as a research design. The researchers used the waterfall method for the development of the project and to meet the objectives of the study. The researchers also floated survey questionnaires and analyzed the results to determine the extent of compliance of the developed system with the ISO 25010 Software Quality Assurance Standards in terms of functionality, efficiency, usability, reliability, maintainability, and portability.

2.2. Waterfall Method

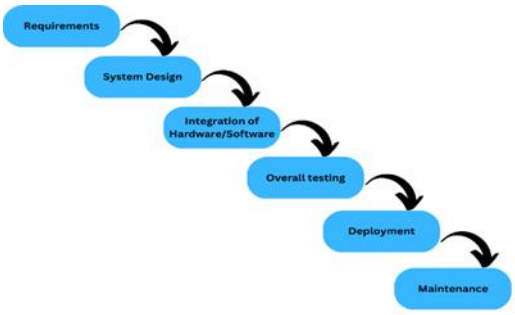

Figure 2-1. The Waterfall Model of the Development Project

2.3. Requirement Gathering and Analysis

The researchers gathered data by performing their own experiment. The researchers diligently collected data on various parameters, including the pH and TDS levels, and the subsequent changes in pH and TDS.

2.3.1. Research Instrument

The researchers chose to use observation as their main research instrument in their experimental study. The researchers were able to gather useful data by carefully studying and documenting the experimentation process.

2.3.2. Data Analysis

The analysis performed was one-way Analysis of Variance (ANOVA). It is used to analyze the pH and TDS readings and determine whether there was a significant difference between among the groups. Prior to doing the one-way ANOVA test, the researchers ran preliminary tests to confirm the validity and reliability of the data analysis. They specifically used the Levene's test and the Shapiro-Wilk test. To evaluate the normality assumption of the data distribution, the Shapiro-Wilk test was used. This test enabled the researchers to determine if the data followed the normal distribution, which is a prerequisite for correctly executing a one-way ANOVA. In order to assess the homogeneity of variances assumption across the groups, the researchers also used Levene's test. These preliminary tests allowed the researchers to confirm that the assumptions of normality and homogeneity of variances were

valid, which gave the assurance to proceed forward with the one-way ANOVA

The ISO data was analyzed using frequency distribution and the Likert scale. All data was collected through questionnaires. Using the Likert scale with a scale of 1 (very low extent) to 5 (very great extent), participants were asked to rate the extent of compliance of the developed system with the ISO 25010 Software Quality Assurance Standards in terms of functionality, reliability, usability, efficiency, maintainability, and portability. The results were documented and served as input for the design of the system.

2.4. System Design

The researchers examined the collected data. The IoT-Based Automated Hydroponic Nutrient Solution Management System's hardware components were chosen and created. The project involves developing Arduino codes to analyze readings from pH and TDS (total dissolved solids) sensors, as well as automating mixing.

The aim of the study is to achieve stability in the readings of both sensors and with the automated mixer. The desired output for the TDS sensor is approximately 560 – 840 ppm, while the pH sensor should read between approximately 5.5 and 6.5. And a Raspberry Pi, the hardware and software were linked to an open-source IoT platform so that output could be watched the real time monitoring of the sensors.

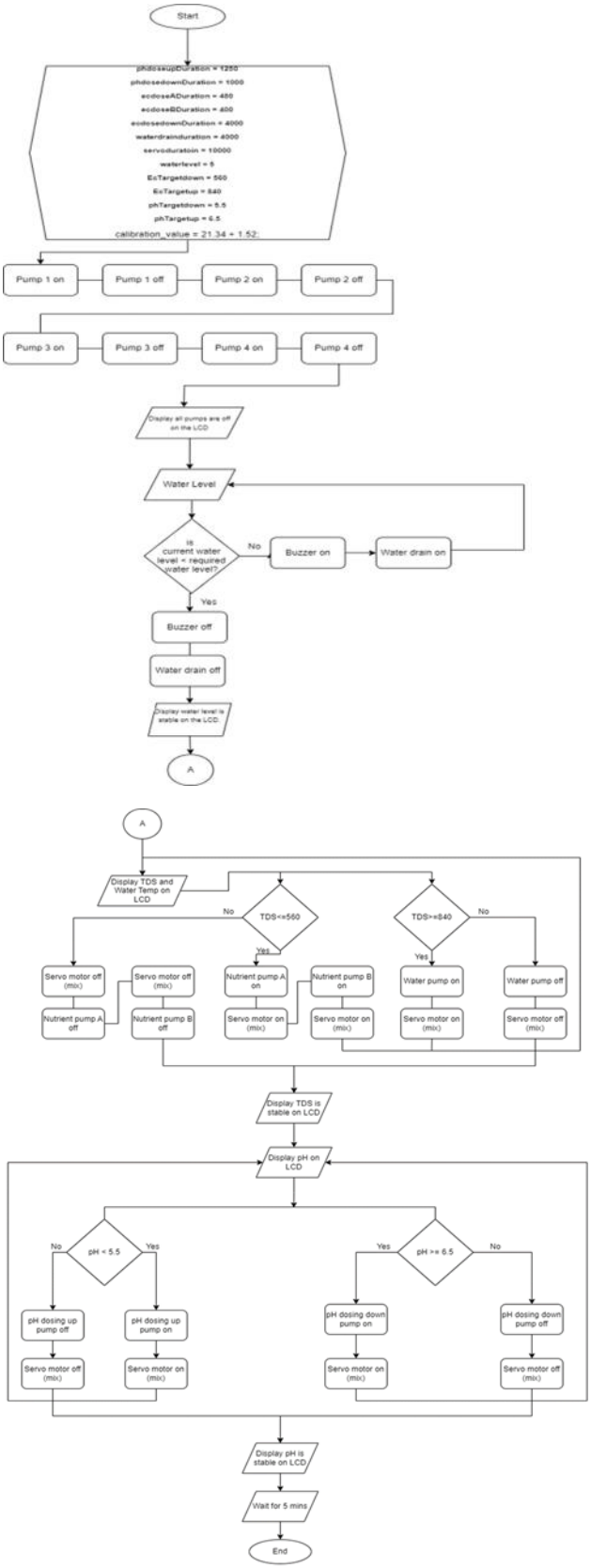

Figure 2-2. The Flowchart of the System

Figure 2-2 shows the flowchart used in the construction of the project. The flowchart

shows the process on how the system will be carried out.

2.4.1. Hardware Design

Hardware development was included in the design of the project. Hardware development shows the different components and materials used in the making of the project, as well as how the hardware components are connected and interact with each other. The major components used in the device are the Arduino Mega, powered by a Raspberry Pi, and the Raspberry PI, which is used to connect the device to the internet and is powered via socket, which are the microcontrollers of the device. The sensors used are pH sensors, which measures the alkalinity or acidity of the water; TDS sensors, which measures the total dissolved solids in a solution; water temperature sensors, which measures the temperature of the water; ultrasonic sensors, which are used to measure the level of the water; a buzzer, which is used to warn the user that the water level is at a critical level; servo motor, which is used for automated mixing; and peristaltic pumps and water pumps, which are used to pump solutions, water, and also draining water.

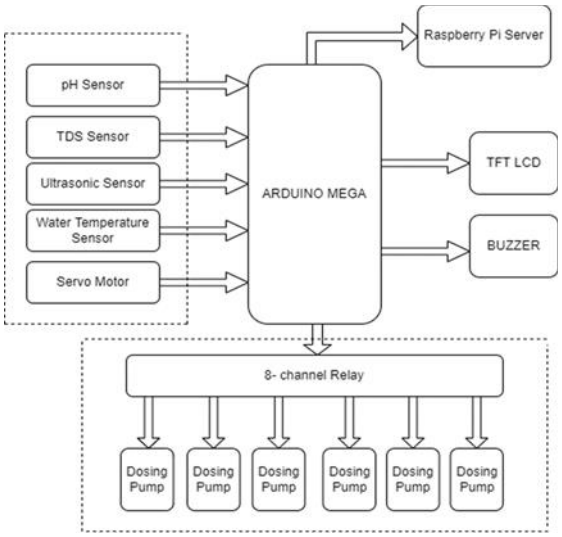

Figure 2-3. The Block diagram of the System

Figure 2-3 shows the block diagram of the system. The device is powered using the power supply of the Raspberry Pi. If the system is ready and installed for hydroponics, it will automatically start and do its job. The user will just monitor the system via the LCD of the device. Then the Raspberry Pi will send the acquired data to the IoT platform to be viewed remotely.

2.4.2. Software Deign

Since the system can't run on hardware alone, software is needed to program the microcontroller while building the IoT-Based Automated Hydroponic Nutrient Solution Management System. To ensure that the desired result is obtained, the microcontroller must be programmed using codes that correspond to the functions of each component of the system.

The software programs needed to create the system are listed below:

- Arduino IDE - The system's intended functionality was implemented by building, compiling, and burning program codes into the atmega328p using the Arduino Integrated Development Environment (Arduino IDE).
- Fritzing - to enable designers and artists who are prepared to graduate beyond prototyping for experimentation to creating a more permanent circuit, Fritzing is an open-source initiative to provide amateur or hobby CAD software for the design of electrical hardware.
- Node-RED - a programming tool for wiring together hardware devices, APIs and online services. It provides a browser-based editor that makes it easy to wire together flows using the wide range of nodes in the palette that can be deployed to its runtime in a single-click.
- Linux- an open-source operating system (OS) for the raspberry pi. An operating system is the software that directly manages a system's hardware and resources, like CPU, memory, and storage. The OS sits between applications and hardware and makes the connections between all your software and the physical resources that do the work.
- Firebase- provides a wide range of backend services, such as real-time

databases, authentication, storage, hosting, and messaging, among others. These services allow developers to build serverless applications quickly and easily, without needing to set up or manage their own servers.

2.5. Testing

The needed codes have all been written to program the Arduino Mega, Raspberry Pi, pH sensor, TDS sensor, water temperature sensor, servo motor and ultrasonic sensor. By accessing the system's webpage, users could keep track of the status of the various parameters. To guarantee that the project satisfied its standards for effectiveness, dependability, usability, functionality, maintainability, and portability, the system was tested numerous times. The results of the evaluation on the extent of compliance of the developed system with the ISO 25010 software quality assurance requirements were described on the Likert scale, which was used to determine the scale.

2.6. Integration

All the codes required for programming the Arduino Mega, Raspberry Pi, pH sensor, TDS sensor, water temperature sensor, servo motor, ultrasonic sensor, buzzer, peristaltic pumps, and water pumps have been completed. The user could monitor the system on site or remotely and have it done its job of automatically correcting pH and TDS as well as mixing. The IoT-based Automated Hydroponic Nutrient Solution Management and System were tested multiple times to ensure that the project met its standards for efficiency, reliability, usability, functionality, maintainability, and portability. Likert scale, which was used to determine the scale and its description based on the results of the evaluation on the extent of compliance of the developed system with the ISO 25010 software quality assurance standards.

2.7. Implementation

Throughout this phase, the device has undergone numerous tests to confirm its effectiveness. The device's actions are recorded. The system is examined for effectiveness, dependability, maintainability, functionality, portability, and usability in accordance with ISO standards. Likert Scale was used to analyze the results.

2.8. Maintenance

All necessary improvements, adjustments, and modifications are made during this phase to guarantee that the system and device continue to work in order to achieve its objectives. To ensure that the system and device can respond to changes over time, repairs and enhancements are required. Support for system users, system and device maintenance, and system and device upgrades are all included in this.

3. RESULTS AND DISCUSSIONS

3.1. System Development

3.1.1. Hardware Design

The major components used in the device were the Arduino Mega, powered by a Raspberry Pi, and the Raspberry PI, which is used to connect the device to the internet and is powered via socket, which are the microcontrollers of the device.

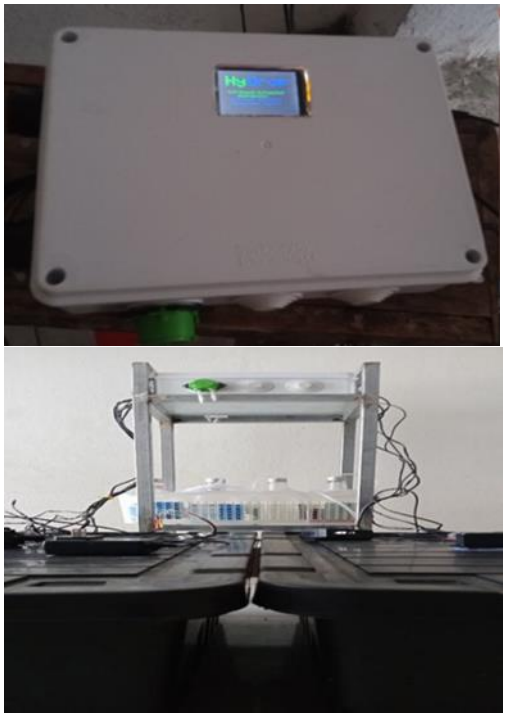

Figure 3-1. The Overall Appearance of the device

The sensors used are pH sensors, which measures the alkalinity or acidity of the water;

TDS sensors, which measures the total dissolved solids in a solution; water temperature sensors, which measures the temperature of the water; ultrasonic sensors, which measures the level of the water; a buzzer, which is used to warn the user that the water level is at a critical level; servo motor, which is used for automated mixing; peristaltic pumps; and water pumps, which are used to pump solutions, water, and also draining water.

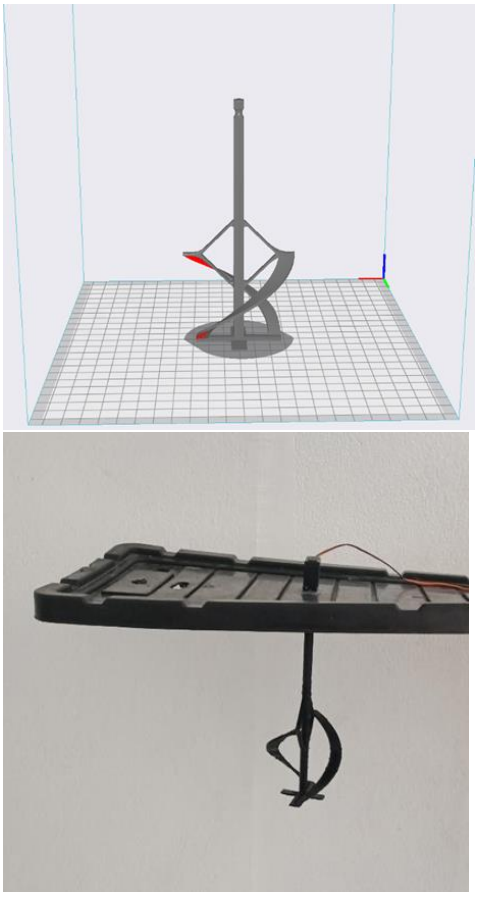

Figure 3-2. The 3D Model (upper) and actual (lower) design of the nutrient tank mixer

3.1.2. Graphical User Interface

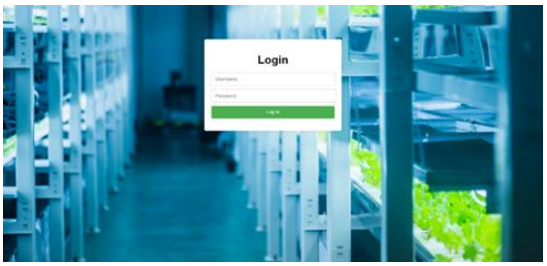

Figure 3-3. The log in page of the webpage.

Figure 3-4. The homepage of the webpage.

3.2. Device Testing

Testing the pH sensor

PH VALUE	DESCRIPTION	STATUS
1	Less than the range	pH UP pump ON
2	Less than the range	pH UP pump ON
3	Less than the range	pH UP pump ON
4	Less than the range	pH UP pump ON
5	Less than the range	pH UP pump ON
5.5	Within the range	pH is stable
6	Within the range	pH is stable
6.5	Within the range	pH is stable
7	Higher than the range	pH DOWN pump ON
8	Higher than the range	pH DOWN pump ON
9	Higher than the range	pH DOWN pump ON
10	Higher than the range	pH DOWN pump ON
11	Higher than the range	pH DOWN pump ON
12	Higher than the range	pH DOWN pump ON

Table 3-1. pH Sensor

Table 3-1 shows the required minimum and maximum pH levels for each peristaltic pump's response depending on the pH level. If

the pH level is lower than the minimum level, the pH Up pump is on, if the pH level is higher than the maximum level, the pH Down pump is on, and if the pH level is in a stable state, nothing happens.

Testing the TDS Sensor.

TDS VALUE	DESCRIPTION	STATUS
100	Less than the range	Solution A and B pump ON
200	Less than the range	Solution A and B pump ON
300	Less than the range	Solution A and B pump ON
400	Less than the range	Solution A and B pump ON
500	Less than the range	Solution A and B pump ON
520	Less than the range	Solution A and B pump ON
540	Less than the range	Solution A and B pump ON
560	Within the range	TDS is Stable
600	Within the range	TDS is Stable
700	Within the range	TDS is Stable
800	Within the range	TDS is Stable
820	Within the range	TDS is Stable
840	Within the range	TDS is Stable
900	Higher than the range	Water Pump On

Table 3-2. TDS Sensor

Table 3-2 shows the required minimum and maximum TDS levels for each peristaltic pump's response depending on the TDS level. If the TDS level is lower than the minimum level, the solution A and B pumps are on, if the TDS level is higher than the maximum level, the water pump is on; and if the TDS level is in a stable state, nothing happens.

3.3. Experimentation

The researchers conducted 5 experiments to record the readings of the pH and TDS sensors in every 1ml drop to stabilize the TDS and pH level of a 20-liter water.

Before conducting the experiment, the researchers considered the length of the microtubes that were connected to the peristaltic pump to ensure proper routing of the nutrient and pH solutions being pumped to the nutrient tank.

Once the researchers measured the appropriate length, the next step was to fill the tubes up to their tips. This ensures that the entire length of the microtubes is filled with liquid, allowing for accurate and consistent liquid delivery from the peristaltic pump. By filling the tubes up to their tips, dose duration was set for every pump. The researchers can guarantee that the liquid being pumped when the device system starts reading the TDS and pH values will be approximately 1 ml. To accurately measure the desired volume of 1 ml, the researchers used a syringe.

LENGTH OF TUBE (LEFT)	DIAMETER OF TUBE (millimeter)	DURATION TO FILL THE PUMP (milliseconds)	DURATION TO DISPENSE 1ml (milliseconds)
24.2 inches	3mm	25460 ms	1250 ms
24.2 inches	3mm	23682 ms	1000 ms
24.2 inches	3mm	1868 ms	480 ms
24.2 inches	3mm	11358 ms	400 ms

PUMPS	LENGTH OF TUBE (RIGHT)
Pump 1 (pH up)	37.2 inches
Pump 2 (pH down)	37.2 inches
Pump 3 (Nutrient A)	37.2 inches
Pump 4 (Nutrient B)	37.2 inches

Table 3-3. The microtubes' length and diameter, as well as their duration to fill.

Table 3-3 shows the diameter and length of each microtube, as well as how long it took each pump to fill a microtube.

# OF DROPS	EXPERIMENT #1	EXPERIMENT #2	EXPERIMENT # 3	EXPERIMENT # 4	EXPERIMENT #5
1	7.4	6.85	6.95	7.03	6.96
2	7.3	6.81	6.92	6.96	6.7
3	7	6.83	6.81	6.95	6.88
4	7	6.78	6.82	6.83	7
5	6.8	6.59	6.71	6.69	6.89
6	7	6.57	6.63	6.81	6.9
7	6.4	6.45	6.57	6.81	6.83
8	-	-	6.21	6.72	6.57
9	-	-	-	6.59	6.7
10	-	-	-	6.61	6.27
11	-	-	-	6.74	-
12	-	-	-	6.48	-

Table 4-4. The raw pH readings in the five experiments.

Table 4-4 shows the number of pH drops it took to stabilize 20-liter water per experiment. The readings should be within the range of 5.5 – 6.5 to consider it stable. As shown, in experiment number 1, it took seven drops to stabilize the 20-liter water. On experiment number 2, it took 7 drops to stabilize the water. On experiment numbers 3,4,5, it took 8, 12, and 10 drops respectively.

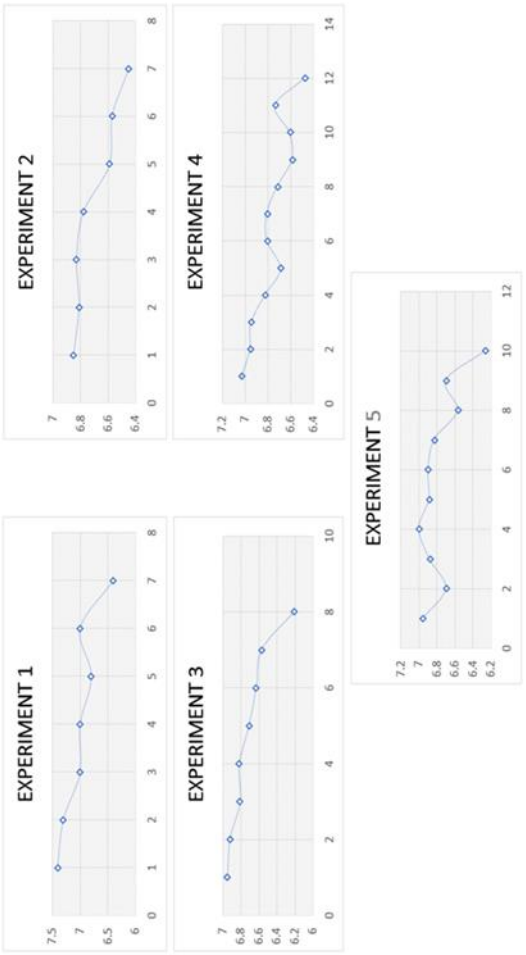

Figure 3-5. The line graphs of the five pH experiments.

# OF DROPS	EXPERIMENT #1	EXPERIMENT #2	EXPERIMENT # 3	EXPERIMENT # 4	EXPERIMENT #5
1	282.47	362.31	293.62	237.15	280.2
2	340.27	367.34	342.81	265.63	292.66
3	360.34	374.05	346.13	296.5	334.21
4	384.46	385.92	372.77	299.37	360.83
5	418.62	399.08	397.74	308.91	390.2
6	428.39	419.03	421.38	315.67	406.28
7	453.23	436.12	455.61	396.84	447.84

8	484.6	457.4	463.48	424.22	455.61
9	503.37	461.06	500.15	443.13	498.05
10	514.07	489.11	521.48	468.56	509.25
11	539.31	511.6	541.31	486.84	520.03
12	567.98	527.8	573.43	535.63	530.22
13	-	542.05	-	544.96	561.08
14	-	561.89	-	586.17	-

Table 3-5. The raw TDS readings in the five experiments**.**

Table 3-5 shows the number of nutrient (A&B) drops it took to stabilize 20-liter water per experiment. The readings should be within the range of 560 – 840 ppm to consider it stable. As shown, in experiment number 1, it took 12 drops to stabilize the 20-liter water. On experiment number 2, it took 14 drops to stabilize the water. On experiment numbers 3,4,5, it took 12, 14, and 13 drops respectively.

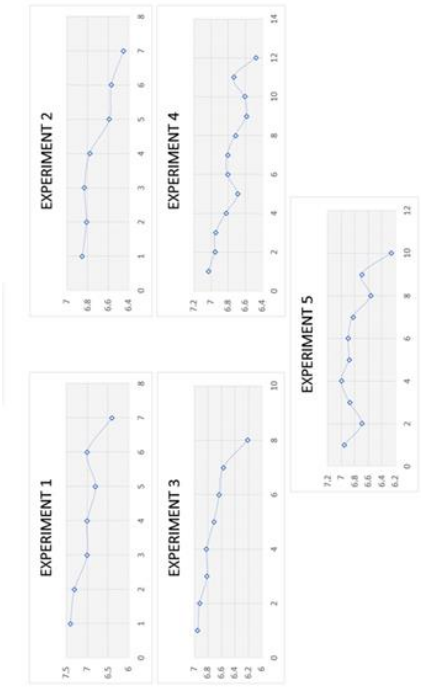

Figure 3-6. The line graphs of the five TDS experiments.

3.4. Checking the Normality, Homogeneity of Variance, and Performing One-way ANOVA on the pH Readings

3.4.1. Checking the Normality of the pH Readings.

EXPERIMENTS	W-STATISTIC	P-VALUE	DESCRIPTION
Experiment 1	0.92516	0.5105	Normal
Experiment 2	0.82695	0.07485	Normal
Experiment 3	0.89358	0.2526	Normal
Experiment 4	0.95116	0.654	Normal
Experiment 5	0.86877	0.09673	Normal

Table 3-6. The Shapiro-Wilk test result of the five pH readings.

The Table 3-6 presents the results of the Shapiro-Wilk normality test for each experiment. It includes the W-Statistic, the p-value, and a column indicating whether the data can be considered as following a normal distribution.

The p-values obtained are all greater than the significance level of 0.05, indicating that there is no strong evidence to reject the null hypothesis of normality for these experiments. This suggests that the data in these experiments can be reasonably assumed to follow a normal distribution.

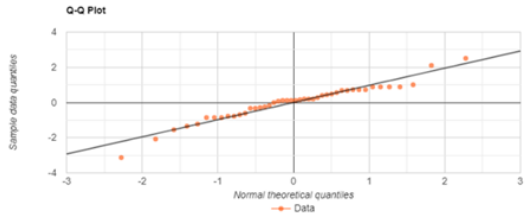

Figure 3-7. The Quantile- Quantile (QQ) plot of the pH readings.

3.4.2. Checking the Homogeneity of the pH Readings

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-STATISTIC	P-VALUE
Groups (Between Groups)	4	0.04946	0.01237	0.5541	0.6972
Error (within Groups)	39	0.8704	0.02232	-	-
Total	43	0.9199	0.02139	-	-

Table 3-7. The Levene's test result of the five pH readings.

To assess the homogeneity of variances across the groups, a Levene's test was conducted. The null hypothesis stated that there is no significant difference in the means of the five experiments.

The results of the Levene's test show that the p-value associated with the F statistic is 0.6972. Since this p-value is greater than the significance level of 0.05, we fail to reject the null hypothesis. This means that there is not enough evidence to conclude that there is a significant difference in the means of the five experiments.

Therefore, the data satisfied the assumption of homogeneity of variances, and ANOVA can be applied to test for significant differences in mean pH values among the five groups.

3.4.3. Performing One-way ANOVA on the pH Readings

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-STATISTIC	P-VALUE
Groups (Between Groups)	0.3897	4	0.0974	2.0530	0.1058
Error (within Groups)	4.3523	38	0.1145	-	-
Total	4.7420	42	-	-	-

Table 3-8. One-way ANOVA result of the five pH readings.

Table 3-8 displays the sum of squares, degrees of freedom, mean square, F-value, and p-value for both the between-groups and within-groups variation, as well as the total sum of squares. The one-way ANOVA test produced an F-value of 2.0530 and a p-value of 0.1058, indicating that there was no significant difference in pH means among the five experiments.

In summary, the one-way ANOVA test revealed that there was no significant

difference in pH levels among the five experiments, as evidenced by the non-significant p-value of 0.1058.

3.5. Checking the Normality, Homogeneity of Variance, and Performing One-way ANOVA on the TDS Readings

3.5.1. Checking the Normality of the TDS Readings

EXPERIMENTS	W-STATISTIC	P-VALUE	DESCRIPTION
Experiment 1	0.9774	0.9711	Normal
Experiment 2	0.93309	0.3369	Normal
Experiment 3	0.97076	0.9186	Normal
Experiment 4	0.9354	0.3625	Normal
Experiment 5	0.94346	0.5033	Normal

Table 3-9. The Shapiro-Wilk test result of the five TDS readings

Table 3-9 shows the Shapiro-Wilk normality test result for each experiment. The W-Statistic, p-value, and a column showing whether the data can be thought of as following a normal distribution are all included.

The normality of the data in each experiment was assessed using Shapiro-Wilk tests. The p-values for all five experiments are greater than 0.05, indicating that the data is normally distributed. Therefore, we can assume that the data follows a normal distribution.

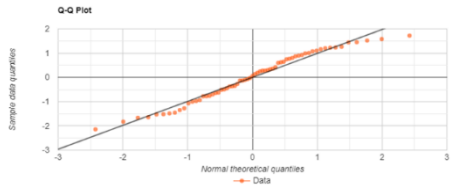

Figure 3-8. The Quantile- Quantile (QQ) plot of the TDS readings

3.5.2. Checking the Homogeneity of Variance on the TDS Readings

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-STATISTIC	P-VALUE
Groups (Between Groups)	4	11922.9246	2980.7312	1.5357	0.2034
Error (within Groups)	60	116458.32	1940.972	-	-
Total	64	128381.2447	05.9569	-	-

Table 3-10. The Levene's test result of the five TDS readings.

In table 3-10, Levene's test was used to determine if the variances in the five experiments were homogeneous. According to the null hypothesis, there is no significant difference in the variances of the five experiments. The test yielded an F-value of 1.5357 and a corresponding p-value of 0.2034.

Based on the results, the p-value (0.2034) was found to be greater than the predetermined significance level of 0.05. This shows that we fail to reject the null hypothesis and that there is insufficient data to prove that the variances in the tests are not distributed equally.

Therefore, the data satisfied the assumption of homogeneity of variances, and ANOVA can be applied to test for significant differences in mean pH values among the five groups.

3.5.3. Performing One-way ANOVA on the TDS Readings

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-STATISTIC	P-VALUE
Groups (Between Groups)	4	18940.0795	4735.0199	0.565	0.689
Error (within Groups)	60	502832.7269	8380.5454	-	-
Total	64	521772.8065	8152.7001	-	-

Table 3-11. One-way ANOVA result of the five TDS readings.

The table displays the sum of squares, degrees of freedom, mean square, F-value, and p-value for both the between-groups and within-groups variation, as well as the total sum of squares. The one-way ANOVA shows the F-statistic value of 0.565 and the p-value of 0.689 that indicates that there was no significant difference in means among the five experiments.

3.6. Quality Assurance

The researchers also conducted a survey to evaluate the extent of compliance of an IoT-Based Automated Hydroponic Nutrient Solution Management System with ISO 25010 Software Quality Assurance standards, which are shown on the table in terms of functionality, reliability, usability, efficiency, maintainability, and portability.

Table 3-12 shows that the IOT-based Automated Hydroponic Nutrient Solution Management System has complied with ISO 25010 standard with the overall mean of 4.47.

NO.	CRITERIA	MEAN	DESCRIPTION
	Functionality		
1	The system accurately measures and adjusts the pH and TDS levels.	4.37	Great Extent
2	The system provides real-time monitoring of pH and TDS levels.	4.60	Very Great Extent
3	The system can be easily programmed to adjust pH and TDS levels based on user-defined settings.	4.60	Very Great Extent
	Reliability		
4	The system operates consistently and reliably over time.	4.40	Great Extent
5	There are no issues with inaccurate measurements or inconsistent dosing.	4.43	Great Extent
6	The system has fail-safe measures to prevent overdosing or underdosing.	4.50	Very Great Extent
	Usability		
7	The system is easy to use and navigate.	4.47	Great Extent
8	The menus and interfaces are intuitive and easy to understand.	4.57	Very Great Extent
9	The system provides clear and helpful instructions for use.	4.47	Great Extent

	Efficiency		
10	The system operates efficiently within specified time and resource constraints.	4.30	Great Extent
11	The system makes efficient use of resources such as water, chemicals, and energy.	4.40	Great Extent
12	There are no bottlenecks or delays in the dosing process that need to be addressed.	4.47	Great Extent
	Maintainability		
13	The system is easy to maintain and service.	4.17	Great Extent
14	There are sufficient documentation and technical support available for maintenance and troubleshooting.	4.40	Great Extent
15	The dosing system can be easily repaired or modified without causing further issues.	4.33	Great Extent
	Portability		
16	The system is easy to maintain and service.	4.37	Great Extent
17	There are sufficient documentation and technical support available for maintenance and troubleshooting.	4.80	Very Great Extent
18	The dosing system can be easily repaired or modified without causing further issues	4.73	Very Great Extent
	Overall Mean	**4.47**	**Great Extent**

Table 3-12. The ISO 25010 Software Quality Assurance Standard compliance.

4. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

4.1. Summary of Findings

Based on the result of the Shapiro-Wilk and Levene's test, the pH readings are normally distributed and have homogenous variances. Based on its one-way ANOVA result, it indicates that there was no significant difference among the five experiments.

Based on the result of the Shapiro-Wilk and Levene's test, the TDS readings are normally distributed and have homogenous variances. Based on its one-way ANOVA result, it indicates that there was no significant difference among the five experiments.

A descriptive analysis was performed to calculate the mean and standard deviation of the pH and TDS measurements gathered to identify how many drops are needed to stabilize a 20-liter water. Based on the findings, the average number of drops per 1 ml of pH that was needed to stabilize a 20 liter of water is 8.8 drops or 8.8 milliliters, while on TDS, the average number of drops needed is 13 drops or 13 milliliters.

Findings showed that the extent of software compliance of the ISO 25010 Software quality standards sub characteristics functional suitability, performance efficiency, compatibility, reliability, portability, and maintainability of the developed system was great extent.

4.2. Conclusions

The proposed IoT-Based Automated Hydroponic Nutrient Solution Management System aims to automate the process of adjusting the pH and TDS levels of the nutrient solution and mixing, saving time, and reducing the risk of human error. The users can access the website that monitors the real-time status of the sensor data remotely, which includes pH, water temp, and TDS but it can only be accessed with the given credentials to log in to the website designed for the system.

Based on the findings of the study, the following conclusions are made.

It can be concluded that the device can be used to automate mixing as well as adjusting pH and TDS levels.

The system can monitor remotely the pH, TDS level, and the water temp via a website to view the sensor data in real time, and it can only be accessed with the correct credentials to log in to the website created for the system's real-time monitoring.

According to hydroponic enthusiasts and IT practitioner, the developed IOT-based Automated Hydroponic Nutrient Solution Management System is an ISO 25010 Quality Assurance Standards compliant.

4.3. Recommendations

Based on the findings and conclusion of the study, the following are recommended:

1. Add features like:
   - Alerts and notifications on the IOT platform.
   - Add a turn on and off switch to the device.
2. Data logging and reporting: Develop a feature that logs the pH and TDS levels over time in a database that can be downloaded from a website and provides users with reports and graphs showing the changes in the solution's pH and TDS levels.
3. Consider enabling users to specify numerous pH and TDS parameters so that the device can alter the dosing levels as necessary.
4. In terms of performance and potential cost savings, utilizing just the Raspberry Pi as the microcontroller is preferable than using both the Arduino Mega and the Raspberry Pi.
5. A larger mixer is required if more than 20 liters of water are utilized; also consider the dimensions and depth of the solution tank, and it should be connected to AC.
6. It is desirable to install the device close to the solution tank so that the solutions released will be equivalent to 1 ml.
7. In the peristaltic microtube where the solutions are dispensed, there will be an intravenous (IV) injection attached; once it is detected by an ultrasonic sensor that it is already equal to 1 ml, the servo will push it to release the 1 ml solution to the solution tank.
8. To avoid water damage, the microcontroller must also be isolated.
9. Along with the water tank and solution tank, there should also be a waste tank that will store excess water from the solution tank

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Iot-Based Portable Soil N-P-K Assessment Device For Hybrid Rice Crop With Fertilizer Recommendation System

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ABSTRACT

Because soil is a natural medium for plant growth, it has a direct impact on crop yield and quality. The soil fertility status refers to the soil's inherent ability to supply adequate amounts of nutrients to plants. Macronutrients are made up of nitrogen, potassium, and phosphorus. The N-P-K label on commercial fertilizer bags is based on these three elements. As a result, controlling these nutrients is critical. However, as observed in the local communities, farmers do not perform this critical step of nutrient control, nor do they perform soil tests. This study aimed to develop an IoT-based portable soil N-P-K assessment device for hybrid rice crops with fertilizer recommendation system. The device was found to be a user-friendly and effective tool for farmers to assess the nutrient levels of their soil in real-time, and the added feature of a fertilizer recommendation system has the potential to improve crop productivity and quality. The device's measurements might not be exactly the same as those obtained from laboratory analysis, however, the device has shown to produce values within the same range, a high degree of similarity between the readings, demonstrating that they are actually quite close to one another. Overall results showed that the design showcase was feasible to be used by farmers and laboratory technician for soil analysis.

KEYWORDS

Soil, analysis, fertilizer, NPK

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1. INTRODUCTION

1.1. Background of the Study

The Philippines is primarily an agricultural country, with the majority of Filipinos living in rural areas and relying on agricultural activities for a living. According to recent data, approximately one-quarter of all employed Filipinos work in the agricultural sector, which is divided into four sub-sectors: farming, fisheries, livestock, and forestry. Farming and fisheries have been the Philippines' most important agricultural sub-sectors due to its terrain and tropical climate. Rice is the traditional crop and the backbone of the rural agricultural economy, accounting for nearly half of all cultivated land. It is nearly three-fourths of the population's staple food. The Central Plain of Luzon is the region's largest producer. In 2020, the sector generated approximately 1.78 trillion Philippine pesos in gross value added (GVA), accounting for 10.2 percent of the country's GDP (Statista Research Department, 2021).

The soil is a valuable and essential agricultural resource. It is necessary for life on Earth. However, because soil formation and development take time, it is regarded as a limited resource. Plants cannot grow in the absence of essential plant nutrients found in soil. N, P, and K are the nutrients that crops require in the greatest quantities. As a result, they are frequently regarded as the most important nutrients. The primary functions of N and P is that they are components of proteins and nucleic acids, both of which are essential components of plant tissue. K is the only nutrient that is not found in organic plant compounds but is essential for the regulation of plant processes such as osmosis and enzyme activity. In general, K is important for the quality of harvested plant products.

Fertilizers are commonly used in Philippine farmlands to improve the productivity and

yield of crops. Farmers often apply fertilizers to their fields to provide essential nutrients to the soil, which can help plants grow stronger and healthier. Nitrogen-based fertilizers, which aid in promoting leaf growth, and phosphorus-based fertilizers, which aid in promoting root growth and flowering, are some of the most popular types of fertilizers used in Philippine farmlands. Farmers may also use other types of fertilizers, such as potassium-based fertilizers, to help balance the nutrient content of the soil and improve overall plant health.

One of the biggest obstacles in the use of fertilizers in Philippine farmlands is the high cost of these goods. Fertilizers are essential for maintaining healthy soil and improving crop productivity, but they can be expensive, especially for small-scale farmers who may not have the financial resources to purchase them in large quantities. This can limit the capacity of farmers to apply fertilizers in the levels needed to enhance crop yields and can result in decreased overall output.

Another challenge is the potential for overuse or misuse of fertilizers, which can lead to negative environmental impacts. Furthermore, excessive use of nitrogen-based fertilizers can result in the production of nitrous oxide, a potent greenhouse gas that contributes to climate change. Proper education and training for farmers on the appropriate use of fertilizers is therefore essential to ensure that they are used effectively and sustainably.

There are several ways and technologies that may be utilized to measure the NPK content in soil. One way to measure NPK levels is through the use of test kits, which are readily available from gardening and farming supply stores. These kits typically involve collecting a soil sample and mixing it with a chemical reagent, which will react with the nitrogen, phosphorus, and potassium levels in the soil to produce a color change. The color of the resulting solution can then be compared to a color chart to determine the NPK levels in the soil. Another way to measure NPK levels is through the use of the developed electronic soil testers. These devices tend to provide a more accurate measurement of NPK levels.

1.2. Objectives of the Study

The researchers' primary goal is to develop a portable soil N-P-K assessment device with fertilizer recommendation system for hybrid rice crops.

The study's specific objectives are:

1. To develop a portable device for assessing soil nutrients particularly nitrogen, phosphorus, and potassium levels for hybrid rice crops.
2. To develop a web-based system for showing soil N-P-K values.
3. To calibrate NPK sensor.
4. To generate the recommended amount of N-P-K in fertilizer.

1.3. Conceptual Framework

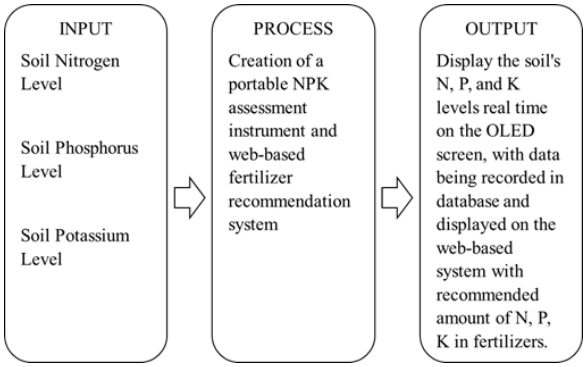

Figure 1-1. Conceptual framework

2. METHODOLOGY

2.1. System Design

A Software Development Life Cycle (SDLC) Waterfall model was used in this study where the entire software development process is broken down into distinct segments. Typically, the results of one step in this waterfall model serve as the input for the subsequent phases in turn. The method was utilized to assess the degree of implementation and the necessity of this study.

2.2. Requirement Analysis

In order to conduct the study, the researcher needed permission from the Subject Adviser, Program Chairman of the Computer Engineering Department of the College of Engineering and Architecture of Cagayan

State University - Carig Campus. Following approval, the researchers started to develop the device and system following the waterfall model mentioned above.

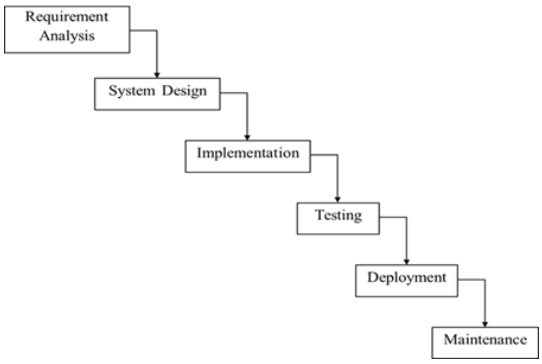

Figure 2-1. SDLC Waterfall Model

The integrated hardware and software development cycle model of the device is shown also in the figure in terms of its construction.

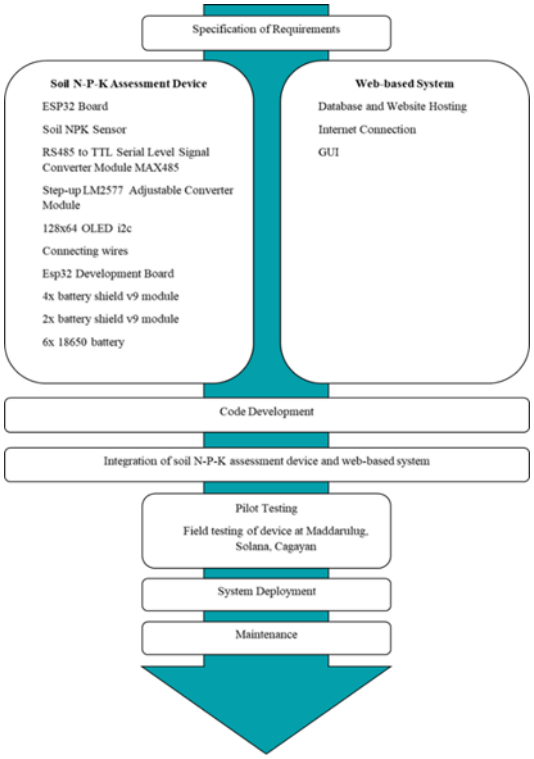

Figure 2-2. Integrated Hardware and Software Development Cycle Model

2.3. Hardware Development

The hardware development of the system is a component of the design of the IoT-based portable soil N-P-K measuring device. It demonstrates the specific parts and supplies utilized to build each subsystem, their interactions with one another, and their individual functions.

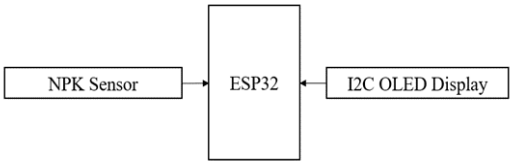

Figure 2-3. Soil NPK Measuring Device Block Diagram

2.4. Schematic Diagram

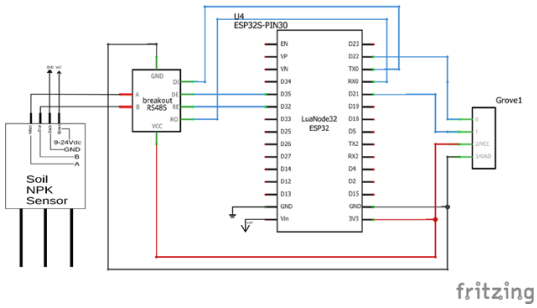

Figure 2-4. Soil NPK Measuring Device Schematic Diagram

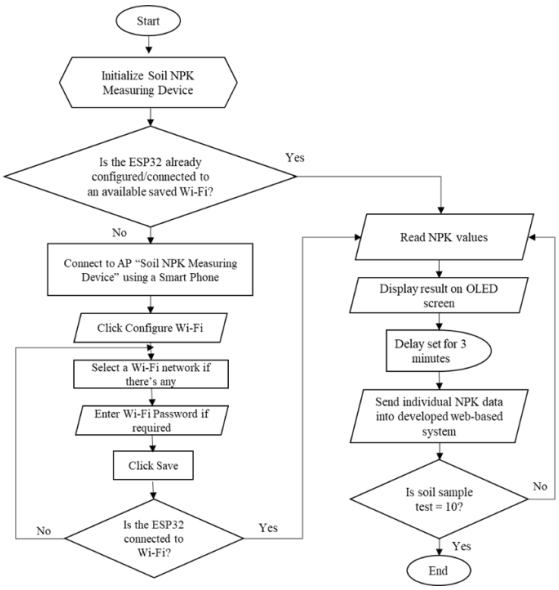

Figure 2-5. NPK Assessment Device Flowchart

2.5. Software Development

The term "Internet of Things" (IoT) refers to a new trend in which a significant number of embedded devices (or "things") are linked to the Internet. These interconnected gadgets exchange data with other devices and people, and frequently send sensor data to cloud storage and cloud computing resources for

processing and analysis to produce significant insights.

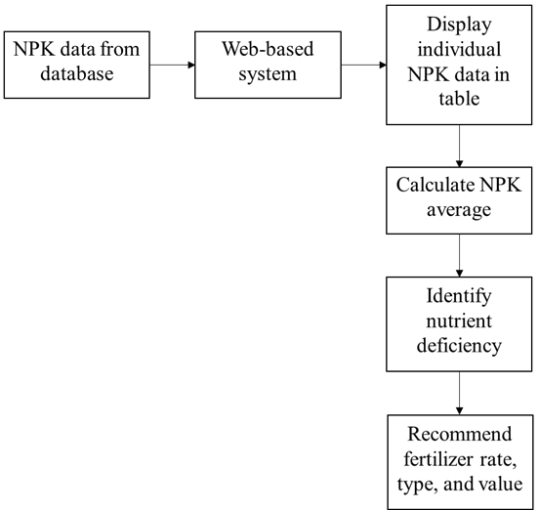

Figure 2-6. NPK Web-based System Block Diagram

Figure 2-6 shows the flow of the system. Depending on which block delivers or receives information or data, each block connects to the other block. The direction of the arrows that connect the blocks serves as a representation of this information or data.

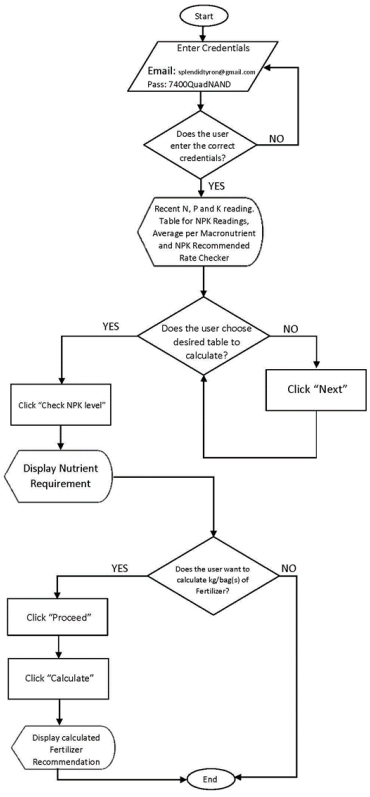

Figure 3-7. Fertilizer Recommendation System Flowchart

3. RESULTS AND DISCUSSIONS

3.1. The Developed Portable Soil NPK Assessment Device

The developed soil NPK assessment device is a portable tool used to identify the levels of nitrogen, phosphorus, and potassium in the soil. These nutrients are essential for plant growth, and their levels in the soil need to be monitored to ensure optimal plant growth and yield. The device includes features such as portability, ease of use, and real-time data display. The collected data can then be used to determine the appropriate amount of fertilizer needed to achieve the desired nutrient levels and improve soil health.

Figure 3-1. The NPK Assessment Device

3.2. DA Macronutrient Analysis

SAMPLE	N*	P	K
A	2.12	8.87	206.10
B	2.48	14.17	308.50
C	1.63	9.27	226.00
D	1.98	9.33	242.90
E	2.03	9.32	234.90

Table 3-1. Macronutrient Readings from Laboratory

*The data under the N column is not pure nitrogen; instead, it contains organic matter, which is used to assess the soil's N status and recommend fertilizer.

The table presents the NPK (Nitrogen, Phosphorus, and Potassium) data report from the analysis conducted by the Regional Soil Laboratory of the Department of Agriculture Regional Field Office 2 Integrated Laboratory Division. The report provides valuable insights into the macronutrient composition of the soil samples examined.

3.3. Initial Device Readings

The succeeding tables show the initial device readings from five lots or areas in Brgy. Maddarulug, Solana town with ten samples for every lot.

LOT	SAMPLE	DEVICE READING		
		N	P	K
A	A1	32	45	91
	A2	42	59	119
	A3	40	56	120
	A4	43	61	122
	A5	42	60	120
	A6	23	33	67
	A7	24	34	69
	A8	24	36	69
	A9	35	50	100
	A10	26	37	74
AVERAGE		33.10	47.10	95.10

Table 3-2. Initial Device Recording for Lot A

LOT	SAMPLE	DEVICE READING		
		N	P	K
B	B1	42	60	120
	B2	49	69	139
	B3	48	68	137
	B4	40	56	112
	B5	58	81	162
	B6	44	62	124
	B7	42	59	118
	B8	40	57	114
	B9	31	43	87
	B10	41	57	115
AVERAGE		43.50	61.20	122.80

Table 3-3. Initial Device Recording for Lot B

LOT	SAMPLE	DEVICE READING		
		N	P	K
C	C1	38	54	108
	C2	40	57	114
	C3	39	55	111
	C4	44	62	124
	C5	25	36	72
	C6	62	87	175
	C7	39	54	109
	C8	40	56	113
	C9	33	47	94
	C10	43	60	121
AVERAGE		40.30	56.80	114.10

Table 3-4. Initial Device Recording for Lot C

LOT	SAMPLE	DEVICE READING		
		N	P	K
D	D1	34	48	97
	D2	51	58	117
	D3	40	56	113
	D4	39	55	111
	D5	37	52	104
	D6	40	56	112
	D7	37	53	106
	D8	42	58	117
	D9	43	60	121
	D10	31	44	88
AVERAGE		39.4	54.0	108.6

Table 3-5. Initial Device Recording for Lot D

LOT	SAMPLE	DEVICE READING		
		N	P	K
E	E1	43	61	122
	E2	42	59	118
	E3	36	50	100
	E4	42	59	118
	E5	55	117	155
	E6	37	52	105
	E7	44	62	125
	E8	37	52	105
	E9	41	57	115
	E10	36	51	102

AVERAGE	41.3	62.0	116.5

Table 3-6. Initial Device Recording for Lot E

SAMPLE	DEVICE READING			DA RESULT		
	N	P	K	N*	P	K
A	33.10	47.10	95.10	2.12	8.87	206.10
B	43.50	61.20	122.80	2.48	14.17	308.50
C	40.30	56.80	114.10	1.63	9.27	226.00
D	39.4	54.0	108.6	1.98	9.33	242.90
E	41.3	62.0	116.5	2.03	9.32	234.90

Table 3-7 Device Readings before Calibration Compared to Readings from Laboratory

3.4. Calibration

In order to determine the margin of error or the typical deviation across all values, the researchers computed the absolute difference between the average value of each macronutrient obtained from the device reading and the target value derived from the analysis conducted at the Department of Agriculture laboratory.

&L TFU (Equation 3-1)

Where:

D is the absolute difference
x is the average of the device reading
y is the reading from the DA laboratory analysis

SAMPLE	N	P	K
A	30.98	38.23	111.00
B	41.02	47.03	185.70
C	38.67	47.53	111.90
D	37.42	44.67	134.30
E	39.27	52.68	118.40
AVERAGE	37.47	46.03	132.26

Table 3-8. Absolute Difference for every Macronutrient

The table presents the absolute difference between the average value of each macronutrient obtained from the device reading and the target value derived from the analysis conducted at the Department of Agriculture laboratory. These differences serve as critical data points for device calibration. By quantifying the disparities between the device readings and the laboratory analysis, the researchers can fine-tune the device's performance and enhance its accuracy. This calibration process is essential for ensuring reliable and precise measurements of macronutrient levels in soil samples.

3.5. After Calibration Readings

LOT	SAMPLE	DEVICE READING		
		N	P	K
A	A1	6.31	0.29	221.9
	A2	4.31	2.71	227.9
	A3	0.31	7.71	238.9
	A4	2.69	11.71	246.9
	A5	0.31	7.71	238.9
	A6	0.69	9.71	241.9
	A7	4.69	14.71	252.9
	A8	7.69	17.71	258.9
	A9	3.69	12.71	247.9
	A10	2.69	11.71	245.9
AVERAGE		3.34	9.67	242.20

Table 3-9. After Calibration Readings for Lot A

LOT	SAMPLE	DEVICE READING		
		N	P	K
B	B1	6.31	1.29	219.9
	B2	1.31	5.71	234.9
	B3	2.31	4.71	232.9
	B4	5.69	15.71	253.9
	B5	2.69	11.71	246.9
	B6	2.69	10.71	244.9
	B7	2.69	10.71	244.9
	B8	4.31	1.71	226.9

	B9	4.69	14.71	252.9
	B10	0.69	9.71	241.9
	AVERAGE	3.34	8.67	240.00

Table 3-10. After Calibration Readings for Lot B

LOT	SAMPLE	DEVICE READING		
		N	P	K
	C1	6.31	0.29	221.9
	C2	4.31	2.71	227.9
	C3	0.31	7.71	238.9
	C4	2.69	11.71	246.9
C	C5	0.31	7.71	238.9
	C6	0.69	9.71	241.9
	C7	4.69	14.71	252.9
	C8	7.69	17.71	258.9
	C9	3.69	12.71	247.9
	C10	2.69	11.71	245.9
	AVERAGE	3.34	9.67	242.20

Table 3-11. After Calibration Readings for Lot C

LOT	SAMPLE	DEVICE READING		
		N	P	K
	D1	1.31	5.71	233.9
	D2	0.69	9.71	241.9
	D3	1.69	10.71	243.9
	D4	7.69	18.71	260.9
D	D5	0.69	8.71	240.9
	D6	0.31	7.71	238.9
	D7	0.31	7.71	237.9
	D8	2.69	12.71	247.9
	D9	4.31	1.71	225.9
	D10	10.69	22.71	268.9
	AVERAGE	3.0	10.6	244.1

Table 3-12. After Calibration Readings for Lot D

LOT	SAMPLE	DEVICE READING		
		N	P	K
E	E1	2.69	10.71	244.9
	E2	1.31	6.71	236.9
	E3	3.69	13.71	249.9
	E4	5.69	15.71	254.9
	E5	0.69	8.71	240.9
	E6	1.69	9.71	241.9
	E7	0.31	7.71	238.9
	E8	1.69	10.71	243.9
	E9	1.31	6.71	235.9
	E10	4.69	14.71	252.9
	AVERAGE	2.4	10.5	244.1

Table 3-13. After Calibration Readings for Lot E

SAMPLE	DEVICE READING			DA RESULT		
	N	P	K	N*	P	K
A	3.25	12.21	247.30	2.12	8.87	206.10
B	3.34	8.67	240.00	2.48	14.17	308.50
C	3.34	9.67	242.20	1.63	9.27	226.00
D	3.04	10.61	244.10	1.98	9.33	242.90
E	2.38	10.51	244.10	2.03	9.32	234.90

Table 3-14. Device Readings after Calibration Compared to Readings from Laboratory

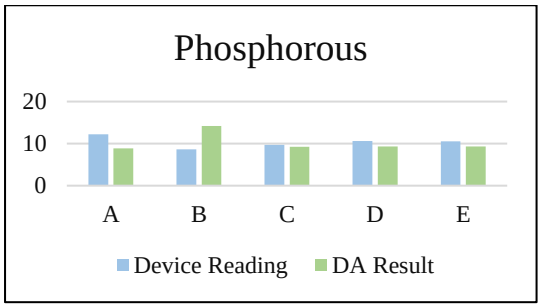

Figure 3-2. Nitrogen device readings compared to DA result readings.

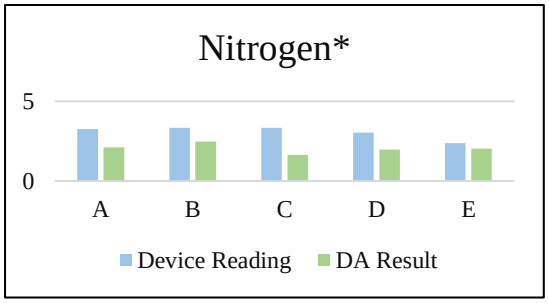

Figure 3-3. Phosphorous device readings compared to DA result readings.

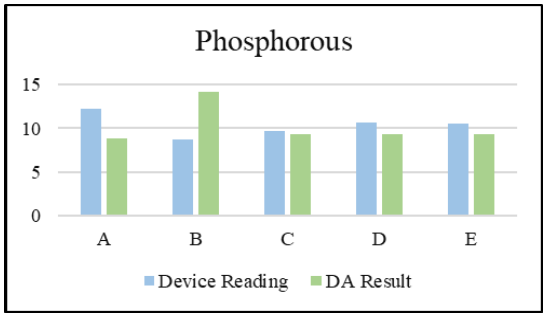

Figure 3-4. Potassium device readings compared to DA result readings.

3.6. Statistical Analysis

To check if two sets of data are significantly the same, the researchers used a statistical test called the t-test. The t-test compares the means of two groups or sets of data to determine if there is a significant difference between them.

An independent samples t-test was used since there are two independent groups or sets of data that needs to be compared. This test determines if the means of the two groups are significantly different from each other. It assumes that the data in each group are normally distributed and have approximately equal variances.

	Variable 1	Variable 2
Mean	85.6472	85.30667
Variance	18710.8	18828.17
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	0.003044	
P(T<=t) one-tail	0.498858	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.997717	
t Critical two-tail	2.776445	

Table 3-15. T-Test Two-Sample Assuming Unequal Variances

Variable 1 or the device readings has a mean (average) of 85.6472, and Variable 2 or the readings from the DA laboratory analysis has a mean of 85.30667. This means that, on average, the values for Variable 1 are slightly higher than the values for Variable 2.

Variance measures the spread or variability of the data. Variable 1 has a variance of 18710.8, while Variable 2 has a variance of 18828.17. This suggests that the values in Variable 2 are slightly more spread out or varied compared to Variable 1.

The hypothesis is that there is no difference in the means between Variable 1 and Variable 2. The hypothesized mean difference is zero, implying that both variables are expected to have the same average value.

The degrees of freedom (df) in this context represent the number of independent pieces of information available to estimate or calculate statistics. In this case, the df is 4, which suggests that there is a small amount of data available for making statistical inferences.

The t Stat is a statistical test that measures the difference between the means of two groups relative to the variability within the groups. In this case, the t Stat is 0.003044, which indicates a very small difference between the means of Variable 1 and Variable 2.

P(T<=t) one-tail represents the probability of observing a t Stat as extreme as the one calculated (0.003044) or more extreme, assuming there is no real difference between the means of the variables. The value 0.498858 suggests that there is a 49.89% chance of observing such a small t Stat due to random chance alone.

The t Critical value is a threshold or cutoff point used to determine whether the t Stat is statistically significant or not. In this case, the t Critical value for a one-tailed test is 2.131847. Since the t Stat (0.003044) is much smaller than the t Critical value, it indicates that the observed difference between the means is not statistically significant.

P(T<=t) two-tail represents the probability of observing a t Stat as extreme as the one calculated (0.003044) or more extreme, regardless of the direction of the difference (either Variable 1 > Variable 2 or Variable 2 > Variable 1). The value 0.997717 indicates a 99.77% chance of observing such a small t Stat due to random chance alone.

The t Critical value for a two-tailed test is 2.776445. Since the t Stat is much smaller than the t Critical value, it reinforces the conclusion that the observed difference between the means is not statistically significant, regardless of the direction.

In the given data, the t Statistic is very small (0.003044), indicating a minimal difference between the data recorded using the NPK Assessment Device and the DA result. However, the critical t value for a one-tailed test is 2.131847, and for a two-tailed test is 2.776445.

Since the calculated t Statistic (0.003044) is much smaller than both the one-tailed and two-tailed critical t values, it suggests that the observed difference between the NPK Assessment Device data and the DA result is not statistically significant. In other words, there is no strong evidence to reject the null hypothesis.

Therefore, based on the provided data, the researchers had accepted the null hypothesis, which states that the data recorded using the NPK Assessment Device is not significantly different from the DA result. This means that the two sets of data are likely to be similar or have similar means, and any observed differences could be due to random chance rather than a true discrepancy between the measurement methods.

3.7. Software Development

The fertilizer recommendation system is a web-based system that helps farmers determine the appropriate type and amount of fertilizer to apply to their crops, based on soil test results and crop requirements. The developed fertilizer recommendation system is designed to provide personalized fertilizer recommendations for farmers based on their specific soil and crop conditions. The system also provides farmers with a user-friendly interface that displays the recommended fertilizer application rates. By using the fertilizer recommendation system, farmers can optimize their fertilizer use, improve crop productivity and quality, and reduce the risk of nutrient losses and environmental pollution.

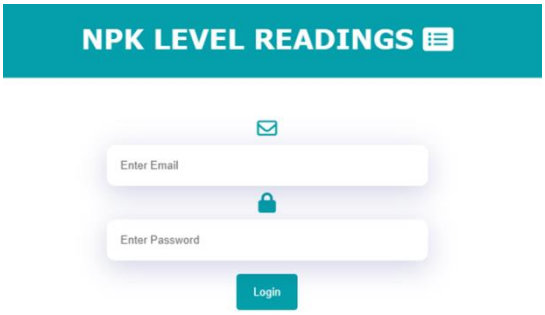

Figure 3-5. System Login Page

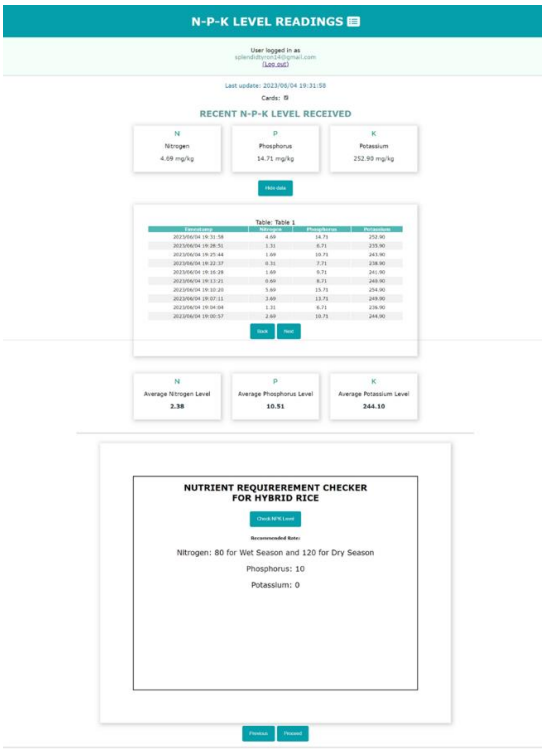

Figure 3-6. Web-based System

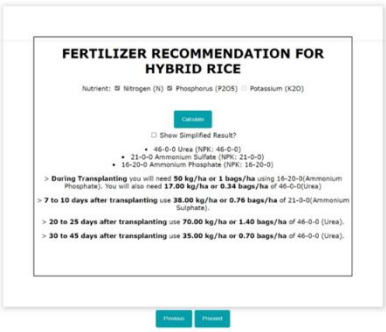

Figure 3-7. Fertilizer Recommendation Calculator

3.8. Fertilizer Recommendation

Nutrient	Nitrogen								
	(% Organic Matter)								
Method of Analysis	Organic Carbon (Colorimetric Method)								
Ranges of Soil Test Results	LOW		MEDIUM				HIGH		VERY HIGH
			Mod. Low		Mod. High				
	0.1 - 2.0		2.1 - 3.5		3.6 - 4.5		4.6 - 5.0		>5
	WS	DS	WS	DS	WS	DS	WS	DS	WS & DS
Hybrid Rice	100	140	80	120	60	100	40	80	0

Table 3-16. Interpretation of Results of Analysis for N

Nutrient	Phosphorous			
	(Available P2O5 ppm)			
Method of Analysis	Olsen Method			
Ranges of Soil Test Results	LOW	MEDIUM	HIGH	VERY HIGH
Hybrid Rice	30	20	10	0

Table 3-17. Interpretation of Results of Analysis for P

Nutrient	Potassium			
	(Extractable K2O2 ppm)			
Method of Analysis	Cold Sulfuric Extraction Method			
Ranges of Soil Test Results	LOW	MEDIUM	HIGH	VERY HIGH
Hybrid Rice	60	45	30	0

Table 3-18. Interpretation of Results of Analysis for K

The results of the NPK analysis presented in the three tables provide valuable insights for interpreting the nutrient composition of the soil samples. These findings serve as a basis for formulating fertilizer recommendations tailored to optimize plant growth and productivity.

For Nitrogen (N), the analysis reveals the level of this essential nutrient in the soil. Based on the results, appropriate nitrogen fertilizer application can be determined to meet the crop's requirements and ensure healthy plant development.

Phosphorus (P) levels in the soil are crucial for root development, flowering, and fruiting. The analysis helps identify the phosphorus status of the soil, enabling recommendations for targeted phosphorus fertilizer application to enhance plant growth and yield.

Potassium (K) plays a vital role in various physiological processes of plants, including nutrient uptake and water regulation. The analysis allows for the assessment of potassium levels in the soil, guiding the recommendation of potassium fertilizers to optimize plant health and resilience.

By considering the NPK analysis results presented in these tables, farmers, agronomists, and researchers can make informed decisions regarding the appropriate types and quantities of fertilizers to apply. This ensures efficient nutrient management, promotes sustainable agricultural practices, and maximizes crop productivity while minimizing environmental impact.

The tables provided are sourced from the Department of Agriculture laboratory.

3.9. Quality Assurance Test

This part of the paper presents the evaluation of the respondents of the extent of compliance of the developed device and system with ISO 25010 Software Quality Assurance Standards in terms of functional suitability, reliability, portability, usability, performance efficiency, security, compatibility, and maintainability.

Indicators		Mean	Descriptive Analysis
Functional Sustainability	Completeness	4.87	Excellent
	Correctness	4.52	Excellent
	Appropriateness	4.57	Excellent
Reliability	Maturity	4.43	Excellent
	Availability	4.78	Excellent
	Fault Tolerance	4.57	Excellent
	Recoverability	4.57	Excellent
Portability	Adaptability	4.74	Excellent
	Durability	4.57	Excellent
	Installability	4.78	Excellent
	Replaceability	4.70	Excellent
	Affordability	4.52	Excellent
Usability	Appropriateness Recognizability	4.65	Excellent
	Learnability	4.61	Excellent
	Operability	4.61	Excellent
	User Error Protection	4.65	Excellent
	User Interface Aesthetics	4.65	Excellent
	Accessibility	4.57	Excellent
Performance Efficiency	Time-Behavior	4.61	Excellent
	Resource Utilization	4.61	Excellent
	Capacity	4.65	Excellent
Security	Confidentiality	4.70	Excellent
	Integrity	4.39	Excellent
	Accountability	4.57	Excellent
Compatibility	Co-Existence	4.61	Excellent
	Interoperability	4.52	Excellent
Maintainability	Modularity	4.61	Excellent
	Reusability	4.48	Excellent
	Analyzability	4.52	Excellent
	Modifiability	4.57	Excellent
	Testability	4.70	Excellent

Table 3-19. Results of Evaluation

The findings from the study indicate that the developed fertilizer recommendation web-based system, has met the rigorous standards set forth in the ISO 25010 guidelines.

Indicators	Mean	Descriptive Analysis
Functional Sustainability	4.65	Excellent
Reliability	4.59	Excellent
Portability	4.66	Excellent
Usability	4.62	Excellent
Performance Efficiency	4.62	Excellent
Security	4.55	Excellent
Compatibility	4.57	Excellent
Maintainability	4.57	Excellent
Overall Mean	4.60	Excellent

Table 3-20. Overall Mean of Evaluation

4. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

4.1. Summary of Findings

The main objective of this study is to explore the potential advantages of a new technological innovation in agriculture that can detect soil nutrient levels, specifically nitrogen, phosphorus, and potassium (N-P-K). To accomplish this objective, the researchers have established specific goals. These include developing a portable device capable of measuring soil nutrient levels, creating a web-based system for displaying and monitoring N-P-K levels, and calibrating the NPK sensor by comparing the device's measured N-P-K levels with laboratory analysis results of the soil. Finally, to generate fertilizer recommendations based on the findings.

Here is the summary of findings:

1. The developed soil NPK assessment device is a portable tool that enables farmers to identify the levels of nitrogen, phosphorus, and potassium in the soil. The device is user-friendly and provides real-time data display, making it easy for farmers to determine the appropriate amount of fertilizer needed for optimal plant growth and yield.
2. The fertilizer recommendation system is a web-based system that helps farmers personalize their fertilizer use based on specific soil and crop conditions, which can lead to improved crop productivity and quality while reducing the risk of nutrient losses and environmental pollution and has passed the strict standards established in the ISO 25010 Software Product Quality Guidelines.
3. The researchers determined the absolute difference for each macronutrient that was used for the

calibration process by analyzing several samples. The researchers have accepted the null hypothesis, stating that there is no significant difference between the two variables. Data analysis showed that the readings are very similar to one another, indicating that they are actually quite close to one another.

4. By obtaining the absolute difference between the average value of each macronutrient obtained from the device reading and the target value derived from the analysis conducted at the Department of Agriculture laboratory, the researchers has calibrated the device's performance and enhanced its accuracy.

4.2. Conclusion

The study on the development of IoT-based portable soil NPK assessment device for hybrid rice crop with fertilizer recommendation system has produced positive results. The device was found to be a user-friendly and effective tool for farmers to assess the nutrient levels of their soil in real-time, and the added feature of a fertilizer recommendation system has the potential to improve crop productivity and quality while reducing the risk of environmental pollution.

After calibrating the device, its final measurements may not be exactly identical to those obtained through laboratory analysis. However, the device has been proven to provide values within a similar range. The readings exhibit a high level of similarity, indicating that they are very close to each other. This conclusion is supported by statistical analysis, which leads us to accept the null hypothesis that there is no significant difference between the two sets of data. Additionally, the device's performance aligns with the ISO 25010 guidelines.

Overall, the development of the IoT-based portable soil NPK assessment device is a step forward in improving agriculture practices and could have significant implications for the future of sustainable farming.

4.3. Recommendations

Based on the findings and conclusion of the study, the following are recommended:

1. Improve the web-based system's ability to compute and evaluate inbred rice crops and other crops other than rice.
2. Improve the web-based system to make complex fertilizer suggestions.
3. Aside from N, P, and K, future researchers can discover and study the amounts of other soil nutrients.
4. A larger display screen is strongly advised.
5. Addition of an indication to alert the user whether data has already been submitted to the database. Light or sound might be used as an indication.
6. Allow general usage of the device and web-based system

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Development of Arduino & Raspberry-Pi Trainer

Edward R. Decena, Karl Stephen O. Evallo[1], Isabelle M. Iglesia[2], and Engr. Gilbert T. Calubaquib

ABSTRACT

Microcontrollers, circuits, and programming are necessary part of Computer Engineering program study field. With all these subjects integrated as one in a device, the project aims to provide the College of Engineering and Architecture Laboratory with a trainer board to be used by students as they pursue Computer Engineering tracks. Also, the project aims to provide means to achieve specific learning objectives of the said program ensuring better understanding and learning outcomes for students without the need for them to buy or possess these microcontrollers, such as the Arduino and Raspberry Pi, are too expensive or costly and uncommon. A startup guide for those who want to learn about microcontrollers and programming are not readily present. To pave way for enthusiast to learn easily a workbook will be a great aid to cater their brilliant ideas.

KEYWORDS

Arduino, Raspberry Pi, Trainer, Workbook

1. INTRODUCTION

1.1. Background of the Study

Nowadays, learning is already made available to everyone, especially with the aid of the internet. Every information that one intends to know about is just a few clicks away but still most of the times learners need to immerse themselves deeper into the things they are learning. Mere information in videos, books, and or other materials on the internet is not enough. Experiencing how things work is much better than theoretical approaches, especially when it comes to technology.

Often if not all the time, students have hard time or struggle to cope with the lesson being discussed by professors/ instructors specially when it comes to technology and hardware. Though, everything is already made available with the use of internet, it is still far different if the students are engaged personally and physically to whatever lessons they are learning instead of watching videos or simulating it using various software. Simulating software makes everything simple but it also simulates a perfect environment where users don't get to experience real world scenarios for example when a component is broken or malfunctioning.

Simulation software can be a useful tool for learning, but it also has some disadvantages. One of the main drawbacks is that it can be expensive to purchase and maintain simulation software. In addition, simulators may not always accurately reflect real-world situations, so the knowledge and skills learned through simulation may not transfer perfectly to real-world settings. Furthermore, simulators can be complex and difficult to use, which can make them intimidate for some learners. Finally, relying too heavily on simulation can prevent learners from gaining hands-on experience, which is often essential for fully mastering a skill.

Experience-based learning is often considered to be more effective than theoretical learning because it allows individuals to apply what they have learned in a practical, real-world setting. This can help them to better understand the material and retain the information for longer periods of time. In addition, experience-based learning often involves active participation and problem-solving, which can be more engaging and stimulating than simply listening to a lecture or reading a textbook. Overall, experience-

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based learning can provide a deeper, more meaningful understanding of a subject and can help individuals develop important skills that they can apply in their daily lives.

Experience-based learning, also known as experiential learning, is a form of learning that involves gaining knowledge and skills through direct experience. Some of the advantages of experience-based learning include: (1) Hands-on learning: Experience-based learning allows learners to actively engage with the material and gain hands-on experience, which can make the learning more meaningful and effective. (2) Real-world relevance: Experience-based learning often takes place in real-world settings, which can make the knowledge and skills more relevant and applicable to learners' lives. (3) Improved retention: Because experience-based learning involves active engagement and involvement, it can lead to improved retention of the material. (4) Increased motivation: Experience-based learning can be more engaging and enjoyable than other forms of learning, which can increase learners' motivation to participate and learn. (5) Development of practical skills: Experience-based learning often involves the development of practical skills that can be used in real-world situations, which can be beneficial for learners' careers.

To meet learning demands, researchers will design a trainer board to integrate Arduino and Raspberry Pi microcontrollers. Aside from microcontrollers, the board will also be equipped with sensors and other components necessary for practical learning.

1.2. Objectives of the Study

The main goal of this study is to develop an instructional material for Cagayan State University Carig Campus College of Engineering and Architecture laboratory.

Specifically, the project aims to:

1. Develop a trainer that can be used to simulate Computer Engineering problems.
2. Develop a workbook and manual for the trainer.
3. Assess the trainer using ISO/IEC 29136:2012 in terms of the following:
   a. Stability
   b. Position of controls
   c. Using readable labels
   d. Consideration of consumable items
   e. Connection

1.3. Conceptual Framework

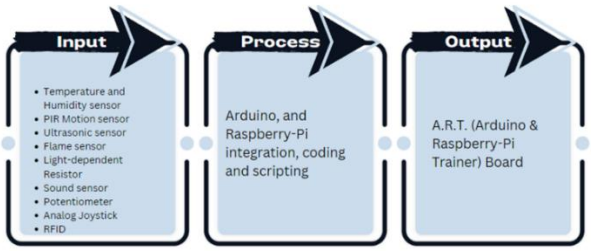

Figure 1-1. Conceptual Framework for the Project A.R.T.

The device conceptual framework is shown in the diagram. The researchers utilized the Input-Process-Output (IPO) model. The project will receive input from the Arduino mega, raspberry pi, sensors, programming scripts and switches. The project will process the input as it compares data from Arduino Mega and Raspberry Pi, performs designated tasks and compiles scripts to render it from the project's output components. Finally, the output will display all the readings from the process into the lcd i2c, LEDs, and other output components.

2. METHODOLOGY

This chapter shows the research design and methods that researchers use to come up with a working prototype and effective research. This will be used to effectively meet the objectives of the research and be a meaningful help to society.

Developmental research uses a different research design, rather than the usual, to meet the objectives of the research. The statistical tool that is used in this type of research should be on point and match what the researchers are aiming for.

The method for this type of research meets the schedule and pace of the researchers, thus,

allowing a more creative but fast-paced working method.

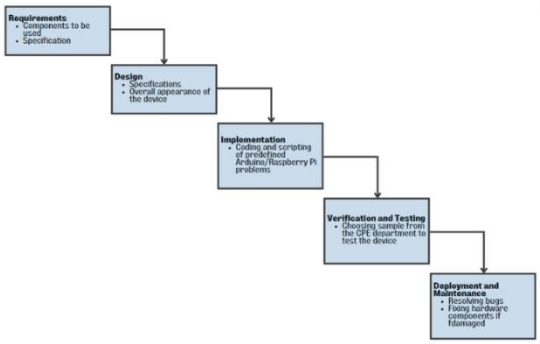

Figure 2-1 – Development of Arduino & Raspberry-Pi Trainer (A.R.T.)

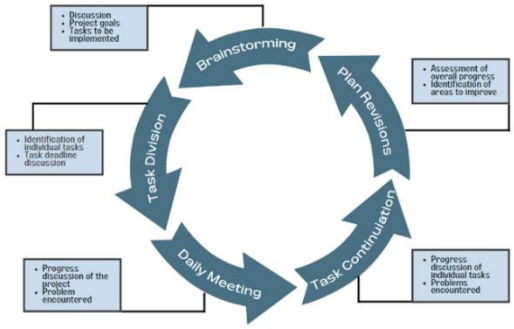

Figure 2-2 - Development of the device cycle

2.1. Research Design

The purpose of this study is to develop an instructional material, specifically a trainer board. To achieve this, the researchers conducted an interview with the laboratory technician regarding equipment from the College of Engineering and Architecture Laboratory which needs further improvement or addition to determine the trainer specification.

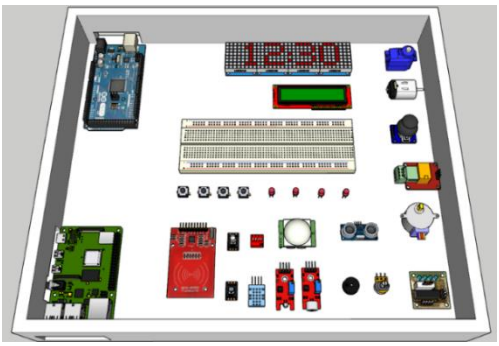

Figure 2-3 – A.R.T. Prototype Design

2.2. Hardware Development

The design of Project A.R.T. includes hardware development of the project. It displays the details of components and materials used in constructing the device, how the components interact with other components, and the function of each component.

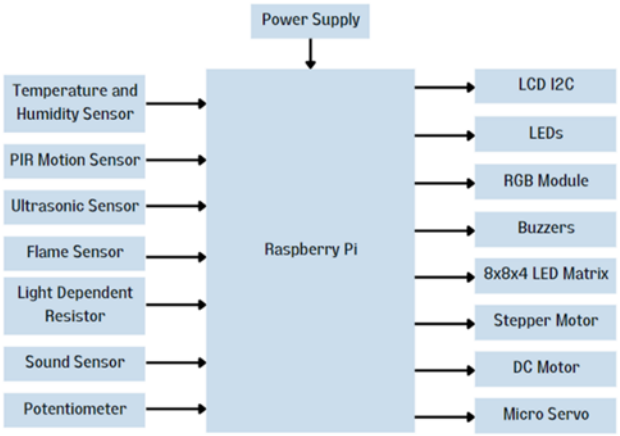

Figure 2-4. Block Diagram Raspberry Pi portion of Project A.R.T.

Figures 2-4 and 2-5 show the components of the blocks. Each block connects to another depending on which block sends and/or receives a signal/information/data. These signals/information/data are represented through the direction of the arrows that connect the blocks. The user of the device will define how he/she would want to use the input and output devices.

2.3. Flowchart of Arduino & Raspberry-Pi Trainer

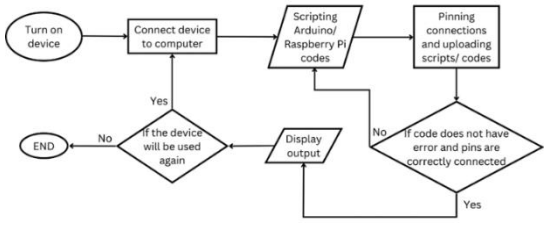

Figure 2-6. Device Flowchart of Project A.R.T.

Figure 2-6 shows the flowchart of the Arduino & Raspberry-Pi Trainer. When the device is to be used it must be connected to a computer to be able to do scripting of the codes of Arduino and Raspberry Pi microcontrollers. After the

coding of scripts, the next thing to do is to connect the pins of the microcontrollers to whatever components are to be used. If the scripts and the connections are without error, the desired output will be displayed, otherwise, scripts and connections must be checked and fixed.

2.4. Research Instrument

A research instrument is a tool or technique that is used to collect data or information for a research study. It can be a questionnaire, survey, interview, observation checklist, or any other method that is designed to obtain reliable and valid data. Research instruments are typically developed based on the research question and objectives, and they must be tested and validated to ensure that they produce accurate and consistent results. The use of appropriate research instruments is critical to the success of a research study, as they provide the means to collect and analyze data in a systematic and objective way.

2.4.1. Data Gathering

It is a research instrument consisting of a series of questions for the purpose of gathering data information. The primary and secondary data gathering tools utilized in this research are both questionnaires using survey scales under a descriptive research method. The content of the principal instrument was prepared by the researchers consisting of how the device conforms to the ISO Standards.

2.5. Data Analysis

The data was analyzed using descriptive analysis. The obtained data was used to describe and assess the trainer on how it conforms to the ISO IEC 29136 2012.

Mean Range	Descriptive Interpretation
4.01 – 5.00	Strongly Agree (Accepted unconditionally)
3.01 – 4.00	Agree (Accepted with minor condition)
2.01 – 3.00	Neutral
1.01 – 2.00	Disagree (Accepted with major condition)
0 – 1.00	Strongly Disagree (Reject)

Table 2-1 Likert Scale Table

3. RESULTS AND DISCUSSIONS

This chapter presents the data gathered, the results of the statistical analysis done and interpretation of findings. These are presented in a chart following the sequence of the specific research problem whose main objective is to construct a trainer board.

3.1. Present COEA Laboratory

The primordial goal of this project focuses on improving or adding equipment in the College of Engineering and Architecture laboratory to aid instructor in delivering the courses of engineering programs better and for students also to learn more efficiently by experiencing the actual.

3.2. Evaluation of Trainer Board According to ISO IEC 29136 2012

The system was evaluated by students using a questionnaire to determine the extent of software compliance of the developed system with the ISO IEC 29136 2012 Standards in terms of stability, position of on/off controls, using readable labels, consideration of consumable items, and connection.

The evaluation findings are listed below.

			Statistic	Std. Error
Stability	Mean		4.5778	.08096
	95% Confidence Interval for Mean	Lower Bound	4.4146	
		Upper Bound	4.7409	
	5% Trimmed Mean		4.6111	
	Median		5.0000	
	Variance		.295	
	Std. Deviation		.54309	
	Minimum		3.00	
	Maximum		5.00	
	Range		2.00	
	Interquartile Range		1.00	
	Skewness		-.768	.354
	Kurtosis		-.536	.695

Table 3-1 Stability (Student Evaluation)

			Statistic	Std. Error
Stability	Mean		4.6667	.21082
	95% Confidence Interval for Mean	Lower Bound	4.1247	
		Upper Bound	5.2086	
	5% Trimmed Mean		4.6852	
	Median		5.0000	

	Variance	.267	
	Std. Deviation	.51640	
	Minimum	4.00	
	Maximum	5.00	
	Range	1.00	
	Interquartile Range	1.00	
	Skewness	-.968	.845
	Kurtosis	-1.875	1.741

Table 3-2. Stability (IT Practitioner Evaluation)

Criteria		Students		IT Practitioners	
Stability		Mean	Description	Mean	Description
1	Pressing of buttons does not cause the device to topple or slip on surfaces where they are intended to be used	4.578	Strongly Agree	4.667	Strongly Agree

Table 3-3 Stability

			Statistic	Std. Error
Position	Mean		4.6222	.06771
	95% Confidence Interval for Mean	Lower Bound	4.4858	
		Upper Bound	4.7587	
	5% Trimmed Mean		4.6481	
	Median		5.0000	
	Variance		.206	
	Std. Deviation		.45422	
	Minimum		3.50	
	Maximum		5.00	
	Range		1.50	
	Interquartile Range		1.00	
	Skewness		-.707	.354
	Kurtosis		-.936	.695

Table 3-4 Position of ON/OFF Controls (Student Evaluation)

			Statistic	Std. Error
Position	Mean		4.5833	.20069
	95% Confidence Interval for Mean	Lower Bound	4.0674	
		Upper Bound	5.0992	
	5% Trimmed Mean		4.5926	
	Median		4.7500	
	Variance		.242	
	Std. Deviation		.49160	
	Minimum		4.00	
	Maximum		5.00	
	Range		1.00	
	Interquartile Range		1.00	
	Skewness		-.456	.845
	Kurtosis		-2.390	1.741

Table 3-5 Position of ON/OFF Controls (IT Practitioner Evaluation)

Criteria		Students		IT Practitioners	
Position of ON/OFF Controls		Mean	Description	Mean	Description
1	A control to turn on/off is located away from the controls in order to reduce the possibility of accidental activation.	4.578	Strongly Agree	4.667	Strongly Agree
2	A control to turn the device on/off is placed in a position where it is easy to be located and activate but not to activate accidentally.	4.667	Strongly Agree	4.5	Strongly Agree
		4.622	Strongly Agree	4.583	Strongly Agree

Table 3-6 Position of ON/OFF Controls

			Statistic	Std. Error
URL	Mean		4.4815	.07150
	95% Confidence Interval for Mean	Lower Bound	4.3374	
		Upper Bound	4.6256	
	5% Trimmed Mean		4.5062	
	Median		4.3333	
	Variance		.230	
	Std. Deviation		.47967	
	Minimum		3.33	
	Maximum		5.00	
	Range		1.67	
	Interquartile Range		.67	
	Skewness		-.554	.354
	Kurtosis		-.630	.695

Table 3-7 Using Readable Labels (Student Evaluation)

			Statistic	Std. Error
URL	Mean		4.3333	.19245
	95% Confidence Interval for Mean	Lower Bound	3.8386	
		Upper Bound	4.8280	
	5% Trimmed Mean		4.3333	
	Median		4.3333	
	Variance		.222	
	Std. Deviation		.47140	
	Minimum		3.67	
	Maximum		5.00	
	Range		1.33	
	Interquartile Range		.83	
	Skewness		.000	.845
	Kurtosis		-.300	1.741

Table 3-8 Using Readable Labels (IT Practitioner Evaluation)

Criteria		Students		IT Practitioners	
Using Readable Labels		Mean	Description	Mean	Description
1	High contrast fonts are used.	4.422	Strongly Agree	4.167	Strongly Agree
2	Text is not overlaid upon images.	4.467	Strongly Agree	4	Agree
3	The labels are essential for operating the device are included.	4.556	Strongly Agree	4.83	Strongly Agree
		4.481	Strongly Agree	4.333	Strongly Agree

Table 3-9 Using Readable Labels

			Statistic	Std. Error
CC	Mean		4.5556	.07146
	95% Confidence Interval for Mean	Lower Bound	4.4115	
		Upper Bound	4.6996	
	5% Trimmed Mean		4.5864	
	Median		4.5000	
	Variance		.230	
	Std. Deviation		.47937	
	Minimum		3.50	
	Maximum		5.00	
	Range		1.50	
	Interquartile Range		1.00	
	Skewness		-.554	.354
	Kurtosis		-1.023	.695

Table 3-10 Consideration of Consumable Items (Student Evaluation)

			Statistic	Std. Error
CC	Mean		4.9167	.08333
	95% Confidence Interval for Mean	Lower Bound	4.7025	
		Upper Bound	5.1309	
	5% Trimmed Mean		4.9352	
	Median		5.0000	
	Variance		.042	
	Std. Deviation		.20412	
	Minimum		4.50	
	Maximum		5.00	
	Range		.50	
	Interquartile Range		.13	
	Skewness		-2.449	.845
	Kurtosis		6.000	1.741

Table 3-11 Consideration of Consumable Items (IT Practitioner Evaluation)

Criteria		Students		IT Practitioners	
Consideration of Consumable Items		Mean	Description	Mean	Description
1	User replaceable consumable items are able to be replaced easily.	4.600	Strongly Agree	5	Strongly Agree
2	The replacement should not require movements that need tight grasping, twisting the wrist or precision gripping.	4.511	Strongly Agree	4.83	Strongly Agree
		4.556	Strongly Agree	4.917	Strongly Agree

Table 3-12 Consideration of Consumable Items

		Statistic	Std. Error
C	Mean	4.7556	.07216

95% Confidence Interval for Mean	Lower Bound	4.6101	
	Upper Bound	4.9010	
5% Trimmed Mean		4.8086	
Median		5.0000	
Variance		.234	
Std. Deviation		.48409	
Minimum		3.00	
Maximum		5.00	
Range		2.00	
Interquartile Range		.00	
Skewness		-1.841	.354
Kurtosis		2.740	.695

Table 3-13 Connections (Student Evaluation)

			Statistic	Std. Error
C	Mean		4.7222	.18088
	95% Confidence Interval for Mean	Lower Bound	4.2573	
		Upper Bound	5.1872	
	5% Trimmed Mean		4.7469	
	Median		5.0000	
	Variance		.196	
	Std. Deviation		.44305	
	Minimum		4.00	
	Maximum		5.00	
	Range		1.00	
	Interquartile Range		.75	
	Skewness		-1.207	.845
	Kurtosis		-.459	1.741

Table 3-14 Connections (IT Practitioner Evaluation)

Criteria		Students		IT Practitioners	
Connection		Mean	Description	Mean	Description
1	The device supports various types if input/output devices.	4.756	Strongly Agree	4.667	Strongly Agree

Table 3-15 Connections

As the criteria above are defined in the ISO Standards, the respondents find all of it being met by the device. The means of each criterion fall between the range 4.00 – 5.00 which means that they firmly agree that the device conforms to the ISO IEC 29136 2012 standard.

3.3. Evaluation of Proposed Trainer Board Workbook

	Relevance	Mean	Description
1.	The workbook is relevant to its intended audience.	4.778	Strongly Agree
2.	It provides useful and actionable information.	4.800	Strongly Agree
		4.789	Strongly Agree

Table 3-16 Relevance

	Clarity	Mean	Description
1.	The content of the workbook is clear and easy to understand.	4.689	Strongly Agree
2.	The instructions and examples are easy to follow.	4.733	Strongly Agree
		4.711	Strongly Agree

Table 3-17 Clarity

	Accuracy	Mean	Description
1.	The information provided in the workbook are accurate and up to date.	4.622	Strongly Agree
2.	The examples and case studies are relevant and current.	4.711	Strongly Agree
		4.667	Strongly Agree

Table 3-18 Accuracy

	Effectiveness	Mean	Description
1.	The workbook does achieve its intended goals and objectives.	4.778	Strongly Agree
2.	The exercises and activities are effective in helping the reader learn and apply the information presented.	4.711	Strongly Agree
		4.744	Strongly Agree

Table 3-18 Effectiveness

	Interactivity	Mean	Description
1.	The workbook does encourage the reader to engage with the content.	4.622	Strongly Agree
2.	There are interactive elements, such as exercises, or discussion prompts, that help the reader apply the information presented.	4.600	Strongly Agree
		4.611	Strongly Agree

Table 3-19 Interactivity

As the trainer device comes with a workbook, the researchers also intend to evaluate whether it could really be a helpful and suitable guide in learning. The results above show that the means of each criterion are between the 4.00 - 5.00 range thus the respondents strongly agree that the workbook meet each of the criterion.

4. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

4.1. Summary of Findings

The researchers mainly aim to develop an instructional trainer board that is efficient and convenient in aiding students learning about microcontrollers in their programs.

1. One of the goals of this project is to improve and add equipment to the College of Engineering and Architecture Laboratory to augment the teaching and learning process of both instructors and students.

   The researchers indeed developed a trainer board which consists of Arduino and Raspberry Pi microcontrollers with many different sensors and components.

2. To complement the development of a trainer device for instructional purposes, the researchers also developed a workbook which will serve as a guide in using and learning the device.

   A workbook was also created which was used as by the instructor a guide in delivering the learning objectives of the course. The teaching method is patterned in the workbook, from its activities, exercises down to problem sets.

3. Lastly, to assure the quality of the device to be developed, the researchers assessed it according to the ISO Standards.

   The gathered and analyzed data presents how well the device conforms to the ISO IEC 29136 2012 standard. The data was gathered from 45 respondents, 15 in each of the 3rd year BS CPE students.

4.2. Conclusion

According to the data gathered, it is concluded that indeed the trainer board is a very helpful addition and improvement in the instructional materials present in the College of Engineering and Architecture Laboratory. This is because students and even instructors do not have to spend much buying their own equipment in learning and delivering specific objectives of the program they are tackling. The workbook provided a step by step and systematic guide for both students and instructors to meet their objectives. From the basics up to the most complicated information was provided which will allow anyone even with zero knowledge of microcontrollers and sensors to learn it easily.

4.3. Recommendations

The research involves the development of an Arduino and Raspberry Pi Trainer Board to aid, improve, and add instructional material or equipment to a college laboratory. The objectives of the research are to conduct a needs assessment, review relevant literature, design and develop the Trainer Board, create instructional material such as a workbook, conduct testing and evaluation, analyze and interpret findings, revise and finalize the workbook, and disseminate the results. The research will involve designing and developing a Trainer Board that incorporates necessary components and interfaces, creating a comprehensive workbook with step-by-step tutorials and practical examples, conducting testing and evaluation in the college laboratory, analyzing the findings, and revising the instructional material and Trainer Board based on feedback. The outcomes of the research will contribute to the knowledge and understanding of Arduino and Raspberry Pi training and can be disseminated through publications and presentations.

According to the findings, the following are the researchers' recommendations:

1. Include different microcontrollers, sensors, and components.
2. Improve the device enclosure.
3. Find a way to make each component more hot-swappable.
4. Develop a learning environment system intended for the trainer board.

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IoT-Based Aeroponics Monitoring and Control System

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ABSTRACT

Aeroponics is an emerging technology in urban farming. However, existing research have focused on system design, neglecting the crucial root chamber aspect. In urban areas, limited land availability and hot climates hinder self-sustaining crop production, worsening food security issues. To bridge these gaps and overcome constraints, this study introduces an integrated aeroponics monitoring and control system empowered by the Internet of Things (IoT). The system incorporates three primary functionalities: monitoring (temperature, humidity, light intensity, water level, and pH level), automation (pump and grow light), and control (fan and humidifier). Comprehensive tests were performed to assess the functionality of each system feature, resulting in a cumulative binomial distribution function of 1. This confirms the proper functioning of the entire system as a cohesive unit. By addressing the root chamber aspect and incorporating IoT technology, this research contributes to the advancement of aeroponics as a sustainable solution for urban crop cultivation. The findings and insights gained from this study have significant implications for improving food security and promoting agricultural innovation in resource-constrained environments.

KEYWORDS

Aeroponics, IoT, Monitoring and Control Systems, Urban Farming

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1. INTRODUCTION

1.1. Background of the Study

The aeroponics system has indeed made a name for itself in urban farming. Its importance has paved the path for a sustainable and more futuristic approach to various aspects, such as food security, environment, and water conservation. Aeroponics is a cultivation system in which plants are grown without soil. In this system, the roots are suspended in air, and the required nutrient mixture for plant growth is provided to the hanging roots in the form of a fine mist. Researchers and farmers alike have leveraged the advantages inherent in aeroponics systems, particularly in terms of increased controllability and nutrition management.

As a dynamic form of technology, the design of the aeroponics system evolves over time. Different forms of technological advancements have been integrated into the system to enhance its functionality and efficiency. One of these advancements is the Internet of Things (IoT), which comprises a network of devices that communicate with each other to make smarter decisions.

The Internet of Things plays an integral role in monitoring aeroponics systems. With IoT, it is possible to monitor parameters such as humidity, temperature, pH, and light intensity within the system. Data from all these parameters can be accessed remotely, providing convenience, efficiency, and increased productivity when applied to aeroponics systems.

Aeroponics is closely associated with the concept of urban farming. Tuguegarao City, the capital of Cagayan, is a densely populated area with the largest population among the 29 municipalities, totaling 120,645 persons or 12.14% of the province's total population as of 2022, according to the Philippine Statistics Authority. The city is congested within a total land area of 144.80 sq. kilometers, with only a

small portion dedicated to food production, such as rice farms. The majority of its food supply is transported from nearby municipalities and provinces, like Isabela. The transportation costs needed to supply Tuguegarao City add to the price of goods, placing a financial burden on the population. Urban farming provides a solution to these challenges by enabling self-sustainability in areas with limited space.

In addition, Tuguegarao City is situated between two mountain ranges, the Sierra Madre to the east and the Cordillera Central to the west, making it prone to receiving high amounts of solar radiation and earning the title of the hottest city in the Philippines. This implies that the variation of plants that can grow here is limited.

With this available technology, the researchers hope to address the aforementioned problems in food supply, not only in Tuguegarao City but also in similar situations throughout the country. With the help of aeroponics and IoT, the researchers aim to develop a lab-scale monitoring and control system that will aid in the production of high-value crops.

Although this study may not be the pioneer in implementing IoT in an aeroponics system, it is the first of its kind to specifically focus on the root chamber of the device to monitor the plant's roots while maximizing its ability to mimic a cold climate by providing a controlled environment for plant growth.

Additionally, this study aims to integrate different useful features into a single system with the purpose of addressing the gaps in past related research, such as the inclusion of a water level indicator and a focus on the root chamber of the system.

1.2. Objectives of the Study

The main objective of this study is to develop an IoT-based aeroponics monitoring and control system.

Specifically, the study aims to:

1. integrate the sensors in the growth and root chamber of the aeroponics system and to monitor the following parameters: temperature, humidity, pH level, light intensity, and water level;
2. automate the following output devices: water pump and grow lights; and,
3. provide manual and automatic control of the following output devices through the Blynk application: fan and humidifier.

1.3. Conceptual Framework

The features of the system are divided into three main categories: monitoring features, automation features, and control features. Monitoring features provide data to the user. The parameters being measured are temperature, humidity, pH level, light intensity, and water level. Automation features are functions of the project that perform actions in the system without any command from the user. Under this feature is the automatic activation of the grow lights when the photoresistor detects that it is too dark in the growth chamber. Pump activation is also included in the automation features. The water pump activation requires the user to set up the time for the misting cycle of the aeroponics system. The misting cycle is a continuous process that provides water and nutrients to the roots of the plants. The user has control to modify the misting cycle based on the crop's needs by setting up the pump's on and off times.

Control features are functions of the system that allow the user to control the activation of the output devices, including the fan and humidifier. Fan and humidifier activation share a similar concept under control features. They can be operated manually or automatically. Manual operation means that the user turns on/off the fan or humidifier by simply using the buttons provided in the Blynk application. On the other hand, automatic operation means that the user provides a range of temperature for the fan activation and a range of humidity for humidifier activation. This range of

temperature and humidity will be used by the system as threshold values to decide on the necessary action in order to regulate the said parameters.

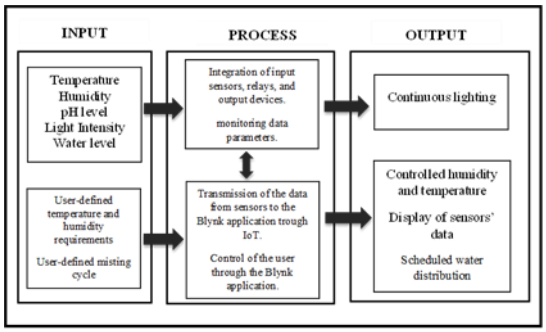

Figure 1-1. Conceptual Framework

In general, the whole system can be simplified into an Input-Process-Output format. The input is composed of the acquisition of different data in the aeroponics system using various sensors: temperature, humidity, pH level, light intensity, and water level sensors. A specialized microprocessor will be utilized to process the collected data and aid in transmitting the information to the IoT platform, which will then be mirrored in the application.

The output will be the data transmitted by the sensors and displayed on the Blynk application (temperature, humidity, water level, light intensity, and pH level). Additionally, continuous light and controlled temperature, humidity, and the schedule of the misting cycle are also outputs of the system. Figure 1-1 summarizes the above-mentioned process into an input-process-output format

2. METHODOLOGY

2.1. Research Design

This study will utilize an experimental research design to develop an aeroponics monitoring and control system using IoT. The objectives of this study are categorized into three main areas: monitoring, automation, and control features. Regarding automation features, the independent variables are the plant watering schedule and light intensity, with the corresponding dependent variables being pump activation and growth LED activation, respectively.

For the control features, the independent variables are temperature and humidity, while the dependent variables are fan activation and humidifier activation.

2.2. Sampling Procedures and Samples

The samples for this study will be obtained from the data collected from various features of the entire system. Random sampling will be implemented as the data collection will be continuous until the desired number of replicates is achieved. For system testing, the sample size will be fixed at 30 replicates.

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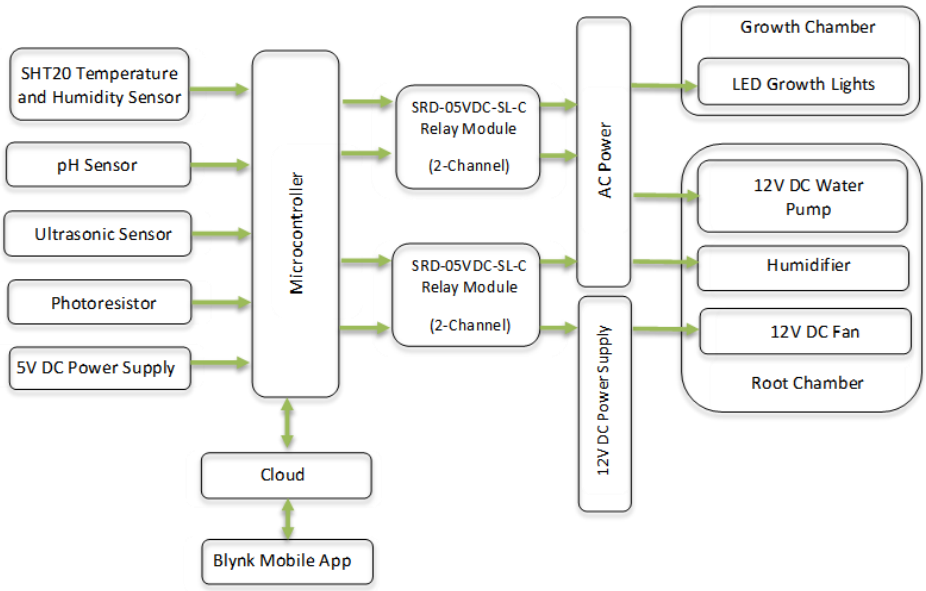

Figure 2-1. Block Diagram of the Aeroponics Monitoring and Control System

2.3. Pre-Experimentation

During this stage of the study, the researchers will prepare and develop the system. This process will be primarily divided into hardware and software development of the system, along with the calibration and/or testing of sensors required for the project.

2.4. Hardware Development

This segment includes the laborious job of developing the hardware component of the system. Figure 2-1 illustrates a block diagram of the aeroponics system. The system is powered by both AC and. It consists of different sensors and actuators that are crucial for the monitoring, automation, and control features of the project.

A more systematic explanation can be achieved by describing the functions of the sensors used in the circuit which can be seen in Figure 2-2. The sensors will be used to provide input parameters to the microcontroller. The microprocessor requires the data collected from these sensors to generate an action as an output based on the programmed instructions.

For monitoring features, the SHT20 sensor will be used for temperature and humidity, a pH sensor for pH level, an ultrasonic sensor for water level, and a photoresistor for light intensity. The microprocessor will utilize the data collected from these sensors to display the parameter readings in the Blynk application through IoT.

The microcontroller continuously monitors the digitized parameters from various sensors, compares them to predefined threshold values, and determines if any corrective action is required based on the current state. If a situation arises that requires action, the actuators are activated to perform the necessary control operation. This application is applicable to both automation and control features.

Automation features reduce human intervention in the system by automating the manual process of activating grow lights and the pump in conventional aeroponic systems. Control features allow the user to either manually control the fan and humidifier or let the system handle the task. The use of relays enables the execution of commands from the Blynk application.

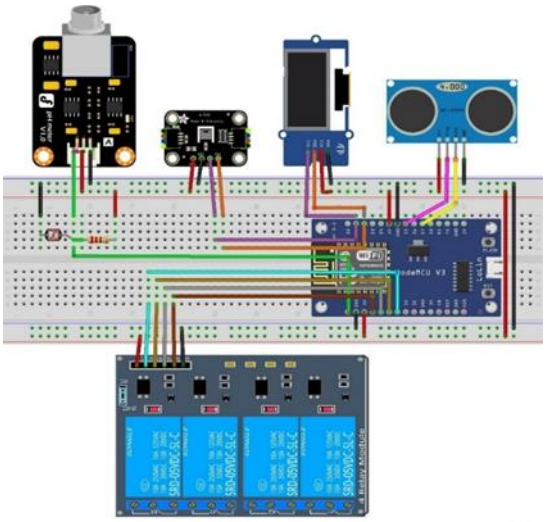

Figure 2-2. Circuit diagram of the prototype.

The output devices of the system will be placed in two different locations. The grow light will be located in the growth chamber, while the fan, humidifier, and pump will be placed in the root chamber.

Figure 2-3 shows the hardware development of the system.

Figure 2-3. Hardware development

2.5. Software Development

The system starts with the initialization of the microcontroller and checks if there is an internet connection available. The sensors will start reading their respective parameters and transmit data to the Blynk application through IoT.

Data from the SHT20 sensor will include temperature and humidity values. The user

can choose between manual or automatic operation of the fan and humidifier. Manual operation means that the user will turn on or off the fan and humidifier by tapping the on/off button in the Blynk application. Auto mode means that the system will use the user-provided requirements. The requirements refer to the range of temperature and humidity that the user will set depending on the crop they will plant.

Auto mode involves a complex process that is crucial for automating the control of the fan and humidifier. If the user chooses auto mode instead of manual mode, the system will force the fan or humidifier into an off state. This means that the default status of the fan and humidifier is off.

For the fan, the next process will be the user setup of requirements. The system requires minimum and maximum temperature values. Therefore, the user needs to input two temperature values based on the temperature requirement for their chosen crop. If the temperature reading from the SHT20 is greater than the maximum temperature, the fan will be turned on. If the temperature reading is within the range of the minimum and maximum temperature, the fan will remain in its previous status. If the temperature reading is lower than the minimum temperature, the fan will remain off. The system will continuously monitor the temperature reading and constantly make decisions, allowing it to take necessary actions to regulate the temperature within the root chamber in real time.

The process for the humidifier is similar to that of the fan with minor adjustments. It also starts with the user setup of requirements. The user needs to input minimum and maximum humidity values based on the requirement of their chosen plant. If the humidity reading drops below the minimum humidity, the humidifier will turn on. If the humidity reading is within the range of the minimum and maximum humidity, the humidifier will remain in its steady state or previous status. If the humidity reading exceeds the maximum humidity, the humidifier will turn off. Just like the fan, the system will constantly monitor humidity readings and execute necessary actions to regulate humidity in the root chamber.

The pH sensor will simply display the pH level on the Blynk application. The ultrasonic sensor will perform a similar process, where its reading will be displayed as the water level.

Light intensity will be displayed on the Blynk application with the help of the photoresistor. If the LDR resistance exceeds 500, the grow light will turn on. If the reading drops below 500, it will remain off. The status of the grow light will continuously be displayed on the Blynk application.

For the automation of water pump, the system will use a predefined misting cycle. The misting cycle refers to the process of constantly turning on and off the pump to provide a continuous water supply for the plant roots. Since different plants require different misting cycles, the system allows the user to set the desired requirement. To set up the misting cycle, the user needs to input the pump off time and pump on time. This duration will be used by the system as a guide for when to turn the pump on and off.

2.6. Experimentation

In the experimental stage, the researchers will test the functionality of the developed features of the study. Data needed for analysis which are stated in the samples portion of the methodology will be recorded.

2.7. Post-Experimentation

To sustainably dispose electronic waste that will be generated in this study, we will collect and keep them for further repurposing and recycling. After the experimental stage, the data gathered will be tabulated and prepared ready for data analysis.

For the testing of the sensors, paired t-test will be used to check if the values collected are close to the standard readings. Cumulative binomial distribution will be used in assessing the data from the system testing. The binomial distribution will determine the functionality of the system.

3. RESULTS AND DISCUSSIONS

3.1. Temperature Monitoring

The cumulative binomial distribution function for temperature monitoring resulting in 1 implies that the probability of successfully displaying the temperature recorded by the calibrated SHT20 sensor in the Blynk application through IoT is 1, or 100%. This means that the system is working perfectly, and there is a high level of confidence that the temperature readings are accurately transmitted and displayed in real-time.

3.2. Manual Humidifier Activation

The cumulative binomial distribution function of the test conducted on the manual humidifier activation is 1. This result suggests that the aeroponics system reliably activates/ deactivates the humidifier when the user taps the humidifier on/off button in the Blynk application.

3.3. Automatic Fan Activation

The test result of the automatic fan activation, analyzed using the cumulative binomial distribution function, yielded a value of 1. This result implies that the system effectively analyzes the given temperature requirements and makes decisions accordingly. It means that the fan reliably turns on when the temperature reading exceeds the maximum temperature, remains in a stationary status when the temperature is within the range of the minimum and maximum temperature, and turns off when the temperature drops below the minimum temperature.

3.4. Automatic Humidifier Activation

The test results, supported by a cumulative binomial distribution value of 1, confirm that the automatic humidifier activation function reliably responds to variations in humidity. This means that the humidifier activates when the humidity drops below the user-defined minimum humidity, maintains its current state if the humidity is within the range of the minimum and maximum humidity, and turns off when the humidity exceeds the maximum threshold.

The overall design of the output and testing of monitoring and automation features of the system are shown in Figures 3-1 to 3-3.

Figure 3.1. Overall Design

Figure 3-2. Testing of the monitoring feature of the system

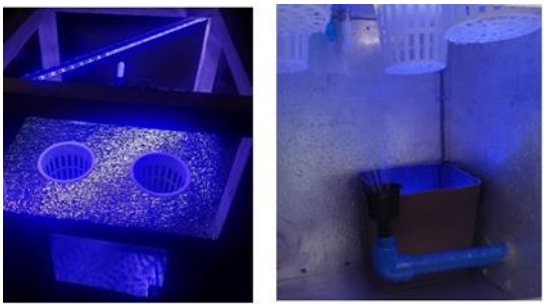

Figure 3-3. Testing of the automation feature of the system

4. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1. Summary

This study presents the development of a prototype that addresses the lack of innovation in aeroponics systems, with a specific focus on the root chamber, and the challenges faced by urbanized and hot-climate regions in cultivating high-value crops. The objective of this study is to design an aeroponics

monitoring and control system with IoT integration.

The system encompasses three main features: monitoring, automation, and control. Rigorous testing was conducted to assess the reliability and functionality of the system. Calibration and testing were performed on the sensors to ensure reliable readings, which are crucial for aiding the system's features. All of the experimental sensors were proven to have readings that did not differ significantly from those of standard instruments.

The monitoring features consist of temperature, humidity, pH level, light intensity, and water level. Through IoT connectivity, data collected from the sensors were displayed in the Blynk application. The tests confirmed the accurate transmission and display of sensor readings, resulting in a cumulative binomial distribution function score of 1 for each parameter.

The automation features include the proper execution of the user-defined misting cycle for the pump and the activation of the grow light. Tests were performed to validate the proper functioning of the water pump within predefined schedules and the activation of the growth LED based on the reading of the photoresistor. Both features achieved a cumulative binomial distribution function score of 1, indicating successful automation.

The control features involve the manual and automatic operation of the fan and humidifier through the Blynk application. The test results indicate that the manual operation successfully activates the two output devices when the user personally turns them on and off using the Blynk application. Test results for automatic fan and humidifier operation imply that the system recognizes the user-defined requirements and utilizes them to execute proper fan and humidifier activation based on the temperature and humidity readings.

Finally, this study demonstrates the successful development and functionality of an aeroponics monitoring and control system, providing growers with comprehensive monitoring, precise automation, and convenient control over key environmental factors. These findings contribute to the advancement of aeroponic technologies and hold great potential for enhancing crop production in various settings.

4.2. Conclusions

This study has yielded significant findings that contribute to the development and functionality of an aeroponics monitoring and control system. The researchers were able to develop an application that monitors, automates, and controls the aeroponics system through the Internet of Things and the Blynk application.

The monitoring features, including temperature, humidity, pH level, light intensity, and water level, have been successfully developed and demonstrated full functionality. The system's sensors were carefully calibrated and tested, ensuring the transmission of precise data over the internet, and presenting it to the user through the intuitive Blynk application. This ensures comprehensive and real-time monitoring of key parameters critical to crop growth and cultivation.

The automation features, such as the water pump and grow light activation, have proven to be highly effective. The water pump consistently activates within the user-defined misting cycle, ensuring proper water and nutrient supply for the plants. Additionally, the grow light automatically activates based on the photoresistor's detection of light absence, providing the necessary light conditions for optimal plant growth. These results confirm the successful development and implementation of both automated functions within the system.

The control features, which involve manual and automatic control operation of the fan and humidifier, have also been successfully developed. The manual control allows users to turn the fan and humidifier on/off through the manual control buttons in the Blynk application. The automatic control operation was proven to function properly based on the test results. This means that when the system

is set to automatic control operation, the user-defined requirements are used as the basis to activate/deactivate the fan and humidifier and to regulate temperature and humidity variations.

Taking everything into account, this study presents a novel aeroponics monitoring and control system that addresses the limitations of existing systems, particularly in urbanized and hot-climate regions. The prototype showcased reliable monitoring, successful automation, and effective control, contributing to the advancement of aeroponic technologies.

4.3. Recommendations

Based on the results and conclusions of this study, the following recommendations are proposed to enhance the project:

1. To ensure uninterrupted operation of the aeroponic monitoring and control system, it is recommended to incorporate a backup power supply. This will prevent system disruptions and maintain continuous functionality even in the event of unexpected power outages.
2. While the fan and humidifier have demonstrated a significant temperature drop, further improvements can be made by exploring additional cooling features. By incorporating advanced cooling mechanisms, such as evaporative cooling or thermal management systems, the system can more effectively achieve and maintain the optimal temperature and humidity levels required for successful marble potato cultivation.
3. For smooth flow of water back into the water reservoir, an inverse pyramid shape is advisable for the base of the root chamber. This will provide an uneven surface that will prevent the water from getting stagnant inside the chamber.
4. Since the grow light provides continuous lighting, it is necessary to improve this feature in consideration of the photoperiodic requirements of plants. These improvements will allow users to set schedules for grow light operation, addressing the different photoperiodic requirements of various crops.
5. The monitoring system will be more effective by creating a historical record of system performance or environmental conditions. It will enable the analysis, visualization, and interpretation of data trends, patterns, and anomalies over time. By collecting and logging data, the aeroponics system can provide valuable insights for troubleshooting, performance optimization, and decision-making processes.
6. Setting up the temperature, humidity, and misting cycle requirements specific to a crop is an additional task for the user. It also necessitates knowledge and research to determine these requirements. By incorporating a crop preset feature into the Blynk application, users can simply select their desired crop, and the system will automatically apply the predefined requirements for that specific crop.
7. In order to validate the efficiency and practicality of the developed system, future researchers are encouraged to include field tests involving the cultivation of actual crops. This will provide valuable insights into the system's performance under real world conditions and allow for adjustments and improvements to be made based on the results.

By implementing these recommendations, the aeroponic monitoring and control system can be strengthened, ensuring its reliability, effectiveness, and adaptability for the successful production of high value crops.

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