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Utilizing Smart Space Technology for Precision Agriculture

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Abstract:
Embarking numerous technological advancement directed at rising and improving the agricultural sector is an idea that the Philippine Department of Agriculture is pushing in preparation to get ahead of the forthcoming dilemma of the new era. This research aims to use smart space technologies in the Philippine agricultural sector that plays a major part in our economy. The proposed concept alludes to the development of a prototype that integrates the Internet of Things (IoT), regarded to be the driving force of smart space technologies, to preserve growth and planting sustainability .This will work by installing a network of sensors that monitor greenhouse agricultural data such as moisture content, temperature, humidity, and pH level, which will be collected and will be transmitted online using a microcontroller. Soil moisture stress will be monitored in real-time and will trigger the sprinkler system once it drops below the threshold point. Based on collected data, factors affecting planting sustainability will be monitored which can give growers and farmers an opportunity to provide proper intervention to help reduce waste and, if necessary, enhance the competitiveness of medium and small sized farmers for high-value agro-products. The output of this study is a simpler and increasingly efficient method of managing and enhancing the yield of farming in greenhouses.

Keywords: *Smart Space, IoT, Argiculture, Wireless Network Sensor, LORAWAN.*

I. INTRODUCTION

Agriculture plays a major part in the Philippine economy as it is deemed a rural nation with 32% of the absolute land [1]. Growth in the agricultural sector is essential for the growth of the country's financial situation, and this is measured as the agricultural sector's added value as a percentage of Gross Domestic Products(GDP)[2]-[4]. According to World Bank data from 1960 to 2016, the average value for the Philippines over the period was 21.36 percent, with 1974 recording the largest proportion of 31.06 while the lowest was recorded with only 9.65 percent in 2016. This demonstrates how dismal our nation's agriculture was as its contribution to the national GDP continues to decline [5][6].

Embarking numerous technological advancement directed at rising and improving the agricultural sector is an idea that the Philippine Department of Agriculture is pushing in preparation to get ahead of the forthcoming dilemma of the new era. In addition, DA considers innovations in information technology by using smart space technologies that would offer farmers access to the necessary crop, soil and environment data to assist them improve the competitiveness of small and medium-sized farmers with high-value agro-products[7]-[9]. This will also tackle the difficulties of tomorrow of increasing the supply of food, placing agriculture's sustainability at one

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point with food security, trade margins and climate change [13]. In order to satisfy this requirement, farmers and agricultural companies turn to the Internet of Things (IoT) for analytics and increase production capabilities [14][7]. The IoT allude to a network of objects, equipment, vehicles, structures, and other electronic sensing gadgets including software for interfacing into the network so as to information's trades. Through the existing network base, IoT can make the subject see the environment and control remotely. The physical world can be coupled with the internet-accessible computer system and virtual resources to offer both valuable data and functionality to end-customers [15][16]. The IoT will push the farming future to the next stage. Smart farming is as of now winding up progressively typical among farmers, and innovative farming is rapidly turning into the standard gratitude to drones and sensors[2].

The basic concept is to boost the development of various crop varieties of excellent quality in a closed setting, generally a greenhouse [9].

The availability of adequate soil moisture levels is critical to effective agricultural manufacturing and to determining sustainability of planting. Too little moisture can lead to loss of output and death of the plant. While too much water is responsible for root disease and wasted water [17]. Likewise, water is a mechanism for delivering any nutrients that are not closely bound to the soil. Therefore, ensuring that the crops obtain the right quantity of water at any specified moment is very essential [18][19].

This research suggested a solution to use IoT by constructing a hardware-based system that can track the soil moisture, temperature, humidity and pH level of the greenhouse facility in a timely manner. The system will automatically activate the sprinkler system during the water scarcity period if the quantity of soil moisture falls below the threshold point.

II. RELATED WORKS

The paper [20] seeks to present a solution to handle the entire checking process technologically to preserve plant development and sustainability such as soil moisture, temperature, relative humidity, and light without requiring the presence of growers.

The authors [21] defined greenhouses as controlled zone condition to develop plants. For the most severe plant development, continuous monitoring and control of abiotic factors are crucial for a greenhouse structure. The researchers also presented equations, shown below, on how different climatic variables will be computed based on values in voltage collected from respective sensors. Shown in Equation 1 below is how temperature will be computed based on voltage reading by DHT11 sensor.

$$Temperature=((Vout\times 100))/(5℃)$$

Equation 1

Equation used to calculate temperature based on the DHT11 sensor output voltage

$$RH=((Vout/Vsupply)-0.16)/(0.0062\%)$$

Equation 2

Equation for calculating relative humidity from the DHT11 sensor output voltage

The authors also explained how the light intensity will be computed using the equations they provided as shown below based on voltage given out by the Light Dependent Resistor (LDR).

(1) $Vout = (5 * RLDR)/(10+RLDR)$

from (1)

(2) $RLDR = (10*VOUT)/(5-VOUT)$

Through integrated Analog to Digital Converter (ADC), this gives Arduino the ability to convert analog voltage into digital signal values ranges from 0 to 1023.

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5/1023 = VOUT/ Analog Reading

(3) VOUT = 0.0048875 * Analog reading

The equation used to calculate the LDR light intensity in Lux:

(4) Lux = 500/ RLDR

RLDR as the resistance of the LDR , VOUT is the analog measure voltage from the LDR, Analog reading is the system voltage or resolution of ADC, and Lux is the illumination calculated.

The authors adopted the IoT based system from their previous study to implement connected farming to provide a suitable atmosphere for growing. In this research, all components used in tracking and nurturing plants are linked wirelessly to the Rasberry-Pi installed via the ZigBee network with the & Cube. Gateways communicate directly with an IoT service server, the Mobius. Mobius not only monitors the environment on the basis of information transmitted by the gateway, but also talks with professional agricultural knowledge systems and control actuators to create the farm appropriate for growing plants[16] .

The study [22] launched the IoT to monitor climate variables in the field such as pH level, soil moisture, temperature, and moisture. Their design of the system can be introduced for any soil type. Using sensors and Zigbee technology, values of different parameters are gathered and tracked which gives them some data loss problems. The setup was performed to fix this problem by installing numerous field-specific soil moisture sensors at the corners and center as the soil moisture differs from end to end. Fields need only one sensor for temperature, IR, humidity, and pH since its values within the field do not vary. All collected sensor values are sent to the cloud using ThingSpeak server for further enhancement.

Authors of [23] enumerated few reasons why Arduino has turned into a mainstream for hobbyists, embedded system professionals and open source hardware designers to make devices and projects that require sensors and actuators to be coordinated. A portion of the advantages of utilizing Arduino boards are: first, it is platform independent. Arduino boards are good in most operating systems, for example, Linux, Windows, and MAC OS contrasted with different boards which are perfect just on Windows Operating System. Besides, it is savvy. Arduino boards are a lot less expensive than different microcontrollers which are viewed as one reason for its overall acknowledgment. The third is that Arduino is easy program. This microcontroller gives basic and simple programming condition utilizing Arduino Software integrated development environment which is straightforward, and vigorous for a wide range of clients. Next is that Arduino is open source hardware. Arduino technology is utilized by different producers and opens the entryway in the making of their own uniquely crafted boards. Lastly, Arduino uses open source software. This technology speaks C++ programming language which enables some C++ libraries to be used and be directly installed into the main program.

According to [24], there are several obstacles to the growth of IoT concepts such as connectivity, energy efficiency, safety, complexity and rapid growth. The author also presented several features of LoRaWAN technology that can be considered viable solution to address the issues in IoT development. LoRa or Long Range is a method designed with spectrum modulation for long-range transfer of information. This method's distinctive feature is the use of a chirping signal that differs continuously with the frequency. A type of LoRaWAN network called Low Power Wide Area Network (LPWAN) involves battery-powered equipment for bidirectional communication. The idea is to lower down the data rate in expense of longer communication ranges. LoRa network utilizes star network topology and its architecture can be split into a back-end and front-end part. The

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back-end is where collected data are stored, while the front-end acts as a bridge between the sensor nodes and the network server. The LoRa communication also operates in an unlicensed frequency band and uses Adaptive Data Rate(ADR) mechanism in managing RF communication power and transfer rate to consume less power and maximize the battery life span. To sum up, LoRa has the following benefits: (1) LoRaWAN uses an unlicensed ISM frequency band ; (2) a versatile solution that can be readily implemented ; (3) can be scaled ; (4) it promotes bi-directional communication ; (5) it offers a high level of safety through the encryption algorithm ; and (6) it offers energy efficiency.

A general structure for the construction of a straightforward in-house IoT system for information sensing as shown in Figure 2 was presented in [25]. The figure demonstrates either Arduino or Rasberry-Pi as an IoT system. The information gathered by different sensors is used as an input as shown on the diagram's top right side. Then again, the output information is displayed as notifications through LEDs, buzzers, and LCDs, as shown in the bottom right half of the figure. The IoT system can be used to control gadgets / machines using actuators and engines to act on the information gathered. Information is traded through a web server between the IoT system and a mobile application. In this way, when needed, the mobile application is regarded as the interface for the client to see, obtain data, or send directions.

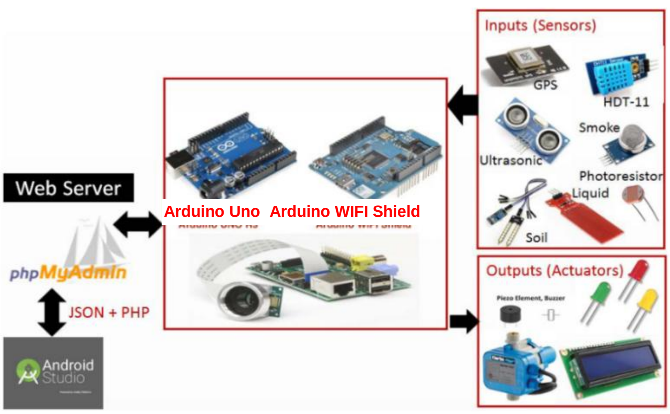

Fig. 1. General Framework to Build and IoT with Sensors [25]

III. METHODOLOGY

The objective of this study is to come up with a solution that will help growers and stakeholders to monitor climatic variables essential in maintaining plant's sustainability. Soil moisture, temperature, relative humidity, light intensity, and water's pH level are some of the factors that greatly affect the plant's growth. If the amount of soil moisture drops below the threshold point, the system will automatically activate the sprinkler system during the period of water scarcity. The proposed prototype uses a wireless sensor network to gather information from the enumerated variables and use LORAWAN technology to send it to the IoT portal. The IoT gateway is responsible for transmitting received data into the webserver via LTE data connection. Uploaded data can be access via web and mobile by creating web interface using PHP and MYSQL database and mobile using Blynk IoT platform for easy access.

A. Sensor Nodes

The study created two sensor nodes. The first sensor node connects only the soil moisture sensor into ESP32 with LORAWAN technology. The moisture sensor is intended to be installed in greenhouse's different sections since water scarcity varies from different locations. The second sensor nodes attach DHT11 for temperature and relative humidity, Light Dependent Resistor (LDR) for light intensity and DFRobot pH level sensor of water pH level detection. The second sensor node will be placed only in one location inside the greenhouse facilities since temperature, light and relative humidity within the facilities do not vary. These sensor nodes utilize LORAWAN technology to transmit collected data into the IoT gateway using radiofrequency. The sensor nodes read and transmit the collected data coming from different sensors to the IoT gateway in an hourly basis.

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Challenges in implementing wireless sensor network are the issue on power consumption and connectivity. LORAWAN was considered to be the solution to these issues since it consumes less power and provides wider range of connectivity.

B. *IoT Gateway*

The IoT gateway is in charge of acquiring collected data from the wireless sensor nodes and transferring it to the web server. ESP32 and Etimes RFM95 RFM95W SX1276 Wireless Transceiver Module LoRaTM Wireless Transceiver were used in the light of its ability to send and receive data through radio frequency utilizing LORAWAN technology and connect to available WIFI connectivity. This makes ESP32 the most appropriate microcontroller to deal with information accumulation from the wireless sensor nodes and to transfers collected data to the web server through WIFI..

C. *Web interface*

The web interface was made to give access and capacity to stakeholders to monitor the fundamental needs essential to the growth and sustainability of the plants. The web module was created utilizing HTML, CSS3, Bootstrap, Mysql, and Jquery. Information related to greenhouse's climatic variables will be shown utilizing tables and graphs for simple comprehension. Giving producers access to this information enables them to provide appropriate intervention to remedial measures if the greenhouse experiences climatic unevenness that may influence the plant's development and yield.

D. *IoT Platform*

The researchers uses Blynk IoT platform to enable growers gain access to data at tip of their palm. Blynk is compatible with different platforms such as Arduino, Raspberry Pi, internet-controlled IOS and Android apps. This enables the designer to simply drag and drop widgets to generate an application and the graphical user interface of the project. With this, stakeholders can monitor the greenhouse condition using their Android phones and give them the ability to control the irrigation system by providing controls that enable them to turn the irrigation system on and off.

E. *Internet Connectivity*

This project uses pocket WIFI to provide internet connectivity to the IoT gateway. The postpaid sim card was also used loaded with a local network data package which is very much available here in the Philippines. The pocket WIFI used is open-line, therefore it gives better options to the growers of which network to use depending on which local network provides available and better service in the area. Since the proposed prototype sends a minimal amount of information into the webserver, this does not require a huge amount of data to maintain and secure data transmission. This is good in the part of the farmers since there will be less expense required for internet connectivity.

IV. CONCEPT DESIGN

The image shown in figure 2 illustrates the design of the proposed system.

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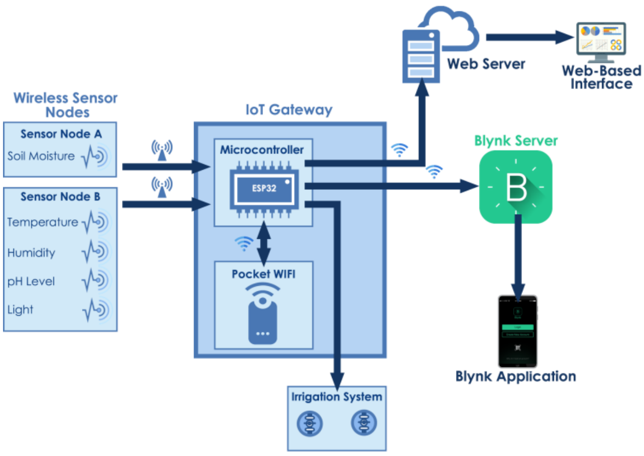

Figure 2. Full block diagram of the system.

V. RESULT AND DISCUSSION

All sensors will be initialized once power was supplied into the wireless sensor networks and the IoT Gateway. All sensors were calibrated to ensure that all data collected are accurate. The IoT gateway, using a real-time clock module, will monitor the time since it needs to send triggers to the WSN when climatic variables need to be measured on an hourly basis. Upon receiving the command from the IoT gateway, each sensor will start collecting their respective data and will send it back to the gateway for processing and uploading. Once data from the sensor nodes were received, soil moisture level will be checked whether it is still under soil's field capacity. Once soil moisture drops its level in its threshold point, irrigation system will automatically activate uring the period of scarcity. To simplify data transmission to the web server, collected data will be concatenated into a single string variable. This will provide an effortless data transmission for the IoT gateway and will consume less data load to complete the process. Once the data is sent to the webserver, the string will be split using explode function in PHP before it will be stored to a MySQL database since the string uploaded is a combined value of each abiotic factors. Internet connectivity from a pocket WIFI using an LTE data connection will be utilized to enable the IoT gateway of transmitting data. All uploaded data can be viewed by growers and other stakeholders on the web interface as displayed in figure 3.

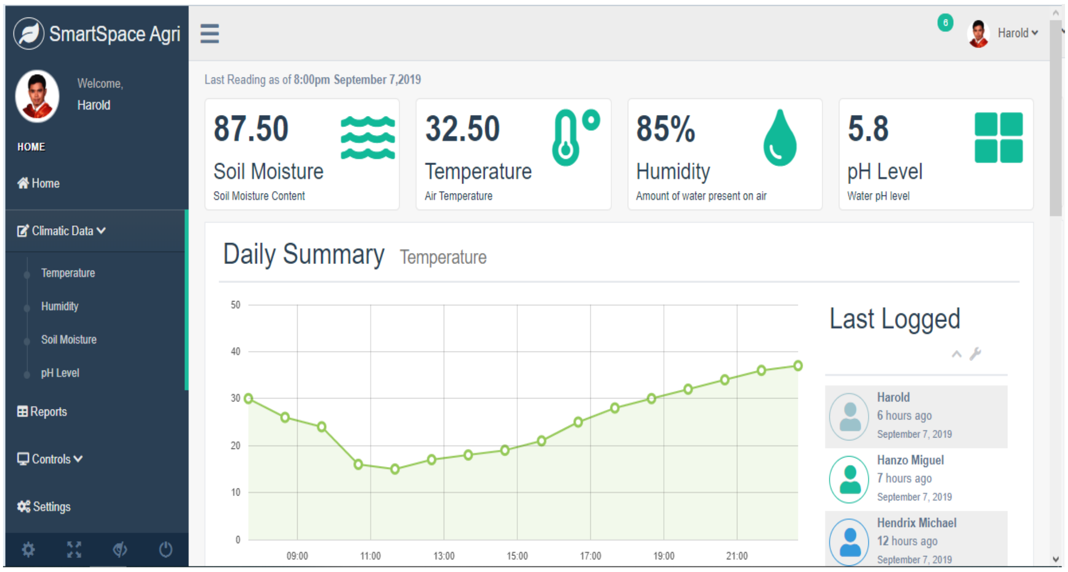

Figure 3. Smart Space Greenhouse Dashboard.

The dashboard of the web interface displays the recently uploaded value of the abiotic factors of the greenhouse facility such as the soil moisture, temperature, humidity, and pH level. Graph of each climatic variables is also available to exhibit the daily readings from each sensor. Each variable has

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pages that display printable historical data which can also be imported into an Excel file.

Figure 4 showcase the interface of the mobile application created using Blynk IoT platform. The application contains gauges that display the recently uploaded data similar to the web interface. The mobile apps also give control to the irrigation system allowing end-user to turn on and off on the valve that manages the flow of water supply for the greenhouse facility. Internet connection is required for the Android-based mobile application to display collected data and provide controls in the controlled environment's irrigation system.

The system was tested for eight hours and was able to collect and upload the required parameters. Data were made available using the web interface as well as the mobile application. During the test, automatic irrigation system was also tested and demonstrated well.

VI. Conclusion

With the advent of latest technologies and the rising popularity of microcontrollers, transforming traditional greenhouses into smart space can easily be achieved. This study focused on utilizing smart space technologies to gather climatic variables that affect the plant's growth to achieve precision agriculture and to help growers increase the quantity and quality of harvest yield regardless of weather condition. The project effectively introduced wireless sensor network to collect information such as soil moisture level, temperature, humidity and pH level together with the capacity to provide the right amount of water at the right time using automated irrigation system. All these information were made available to the stakeholders thru the web interface and the mobile application thru the use of Blynk IoT platform. Moreover, the idea of employing the concept of data mining to the collected data was recommended to further improve the project.

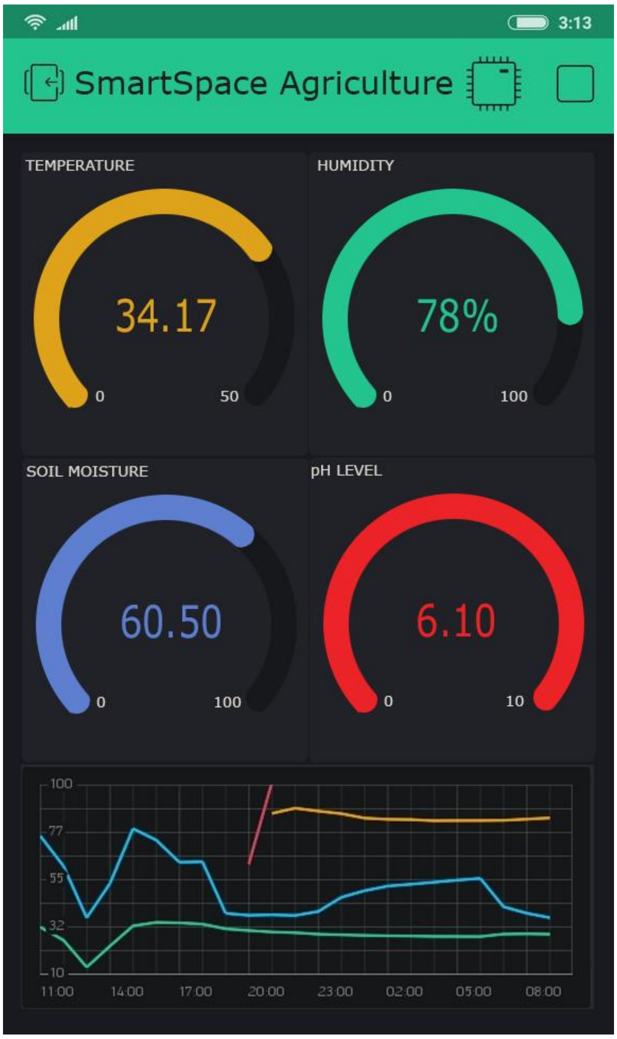

Figure 4. SmartSpace Argiculture Blynk App

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