Internet of Things Hydroponics Agriculture (IoTHA) Using Web/Mobile Applications

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Abstract - Hydroponics agriculture is the type of farming that is carried out with water and nutrients to form nutrient solution for plants growth without soil. Internet of Things (IoT) technology is the technology that has applications in various departments of human life. It can be used to monitor and control the nutritional and environmental growing parameters needs and supply to plants. The objective of the study is to develop an internet of things driven automated hydroponics testbed and cultivate tomato as a use case, harvest data relating to its varied nutrients requirements and observe productivity indicator. If the plants grows well, it will be treated as such without further evaluation. Methodology used includes review of related theory and principles of system design. The experiment results shows that the plants grow well based on the evidence recorded by computer vision and visual look. The plants were monitored and controlled for six (6). Farmers should adopt this method of farming, as it is a solution to limited agricultural land that is bringing about declination in agricultural production capacity.

Key Words: Iot, Hydroponics, Web, Mobile, Agriculture, Technology

1. INTRODUCTION

The desire for eating freshly, locally and organically produced vegetables and herbs has become a major topic in this day and time [2]. It is good, if seasonal vegetables can be produced all year round, with the use of soil, but here in Nigeria, challenges of climatic condition and the need for land use for social economic activities such as: Shelter, Transportation, Urbanization and Industrialization, hinders this project. Another issue that we have, is insecurity such as: Kidnapping, Animal rustling, Boko haram, Gun men attacks to lack of relevant agricultural technology appreciation and application by stakeholders (Farmers, Government and Extension Agents). There is also a general problem of Soil infertility. Unguided resources allocation and utilization. Crops get contaminated by certain chemicals underground and could be harmful to consumers. So, as it is now, using soil as a medium for growing plants is becoming an issue in Nigeria and globally, therefore, there is a need to adopt a more viable alternative of farming known as hydroponics. Hydroponics farming is the type of farming that does not involve the use of soil as growing medium for crops. All that it requires are nutrients solution, air, water, right temperature, relative humidity, potential hydrogen (pH) and electrical conductivity (EC), farming can take place all year round. Products from this farming technology are of high quality as compared to the conventional method of farming.

Therefore, adoption of this farming method for growing our own crops individually and collectively all year round for our food need is the way to go, but with an automation system that will address unguided resource allocation by nature and utilization by the crops and the security challenges. For example, [2] in his research work, was able to determine the range at which an automated hydroponics system can regulate pH and nutrient levels in the farm. He stated that in the future, in order to effectively improve the system, the data gathering procedure must be longer as larger data would have produced better result for data analytics. Similarly, [3] in their research work (Role of information Technology on Agricultural Productivity in Nigeria) found out the status of Information Technology on Agricultural Productivity in Nigeria, challenges and way forward.

1.1 Aim and Objectives of the Study

To innovate an automation model using web/mobile applications that will ensure operational efficiency in hydroponics agriculture based on internet of things technology (IoTT), and system development life cycle (SDLC).

The Specific Objectives are:

1 To develop an Internet of Things (IoT) driven automated hydroponics testbed
2 Cultivate tomato as a use case, harvest data relating to its varied nutrients requirements and observe productivity indicator
3 The productivity indicator of plants, will be evaluated using the growth attribute, if the plant grows well, it will be treated as such without further evaluation/validation. Visual look and computer vision are used to implement these. Computer vision is implemented by using the microcontroller ESP32 CAM.

2.0 Literature Review

The purpose of this chapter is to review literature that are directly related to the current study. A survey of the literature related to Internet of Things Hydroponics Agriculture Using Web/Mobile Applications to improve operational efficiency in Nigeria and those that are related directly to the aims and objectives of this research are brought out in this chapter. The literature review provides a sound conceptual, theoretical and practical understanding of developing an automation model that can monitor and control a hydroponic vegetable farm based on the concept of internet of things.

[1] Was a research work done on Monitoring and Controlling System for Hydroponics Precision Agriculture Based on the Internet of Things concept and Fuzzy Logic. Internet of Things is utilized to enable regular monitoring of plants nutrition and water needs, while fuzzy logic is used to control the supply of nutrition and water to the plants. The experiment result shows that the system can produce better growth for lettuce and bok choy plants in terms of the size of leaves.

Internet of things is currently a novel trend of technology that connects and communicates electronic devices and tools such as computers, cell phones, cars, refrigerators, televisions and so on with each other through the Internet. [3] Effective communication of agricultural information to farmers is crucial in achieving optimum efficiency in agricultural production in Nigeria. Information technology (IT) can help an average Indian farmer to get relevant information regarding agro-inputs, crop production technologies, agro processing, market support, agro-finance and management of farm agri-business, Information technology (IT) in this information age has been recognized as an essential medium of disseminating information and advice to farmers. In Nigeria today, the concept of information technology (IT) has become a global concern and the increasing application of the technology in every segment of our natural life, especially through the GSM, radio, television, projectors, internet, video, camera, computers, has been felt.

[3] Information technologies are increasing day by day among different communities for obtaining the information about related issues, problems and their solutions. In the context of agricultural production, information and communication technologies have played important role in developing countries. Most of the developing countries have obtained fruitful results from the use of new technologies. Internet, mobile phones, radio and television are the most important tools of communication providing knowledge and information to farmers about agriculture. Furthermore, mobile phones have reduced the gap among farmers and buyers. Farmers now communicate directly with customers and get a better price for their products in the market. Mobile phones have also provided new approaches for farmers to get, for example, the latest information from the metrological department for weather conditions before using pesticides in their farms. However, internet is also disseminating information regarding prices and marketing of goods and farmers are receiving information within minutes from all over the world.

Radio Frequency Identification (RFID) technology, which has already proven to be extremely effective in tracking and identifying people and products for logistic purposes, can be applied to the agricultural sector in two ways – production management (from tracking growth and reproduction records to integrating transportation information) and inventory management (from boosting operational efficiency to minimizing loss and damages).

[4] Researched on Soilless Farming – A key Player in the Realization of “Zero Hunger” of the Sustainable Development Goals in Nigeria. They were able to prove that Soilless Farming if adopted can lead to zero hunger in Nigeria and the world.

2.1 Internet of Things (IoT) Technology

It's been long since sensors were introduced in the agriculture operations. But the problem with the traditional approach of utilizing sensor technology was that we were not able to get the live data from the sensors. The sensors used to log the data into their attached memory and later on we were able to use it.

With the introduction of Industrial IoT in agriculture, far more advanced sensors are being utilized. The sensors are now connected to the cloud via cellular/satellite network. Which lets us to know the real-time data from the sensors, making decision making effective.

The applications of IoT in the agriculture industry has helped the farmers to monitor the water tank levels in real-time which makes the irrigation process more efficient. The advancement of IoT technology in agriculture operations has brought the use of sensors in every step of the farming process like how much time and resources a seed takes to become a fully-grown vegetable.

Internet of Things in Agriculture has come up as a second wave of green revolution. The benefits that the farmers are getting by adapting IoT are twofold. It has helped farmers to decrease their costs and increase yields at the same time by improving farmer's decision making with accurate data.

[5] Internet of things in smart environment, concept, application, challenges and future directions. Here the authors focus is on the environmental study based on internet of things technology and discuss the justification behind the use of internet of things in the field of environmental studies.

According to [6] Internet of things for Smart Agriculture: Technologies, practices and future direction. Investigation is made into those sensor enabled internet of things system that provide intelligent and smart services towards smart Agriculture.

According to [7] Smart Farming System: Monitoring and Controlling of Some Agricultural Features Using an Arduino Based System. The author deals with smart farming system which would allow farmers access to live data such as temperature, humidity, potential hydrogen and moisture etc.

2.2 System Analysis, Methodology and Design

Research is a systematic investigation or the study of objects (things) and their origins so as to bring out data (facts) and on the basis of that facts, conclusions can be drawn.

In the innovation of the automation system for growing hydroponics plants/crops, methodologies such as: Review of related literature and the principles of system design are involved to meet users' requirements.

[8] Provide workable steps to the design and implementation of a hydroponics control system. He further talked about the importance of open source controller. With the open source controller it could become cheaper to obtain and many people can go into hydroponics farming.

2.3 Analysis of the Existing System

The existing system is the work already done by [1] the authors implemented a monitoring and controlling system for hydroponics precision agriculture based on the internet of things (IoT) concept and Fuzzy logic. IoT is utilized to enable regular monitoring of plants nutrition and water needs, while fuzzy logic is used to control the supply of nutrition and water to the plants. Logic control used in the system consisted of four inputs from the sensors, namely the potential hydrogen (PH) value, electrical conductivity (EC) value, water level value, and air temperature value. The experiment result shows that the system can produce better growth for lettuce and bok choy plants in terms of the size of leaves.

[9] Developed an entirely automated plants/watering system to be used to conserve the wastage of water. Here, the plants are watered efficiently till the desired value is reached and the pumped is switched off automatically. They used GSM technology to collapse distance so farmers can get information about their farms from anywhere.

[10] Stated that, there is a need to ensure the availability of inexpensive and quality products to meet the increasing food demands of the population. Therefor intensification of growing practices in technology is necessary.

2.4 Limitation of the Existing System

The existing system consists of five major modules, i.e., ESP8266 microcontroller module, PH sensor module, EC sensor module, water level sensor that is connected to relay and pumps, and humidity sensor module design that is connected to a servo to open or close the paranet curtain. In designing the application to be able to control each input from the sensor and output to be carried out, the author used the C language.

The existing system have the limitations of not making provision for security management, no provision for water temperature control, used paranet curtain to control environmental temperature, there is also no provision for light to the plants. The formula for nutrient for growing crops not revealed. Planted two varieties of crops. There are four sensors used in this research,

i.e., PH sensor, EC sensor, the water level sensor, and the humidity sensor.

2.6 Justification of the Proposed System

This research is titled: **Internet of Things Hydroponics Agriculture Using Web/Mobile Applications.** In this proposal, our concern is innovating an automation system for hydroponics agriculture based on internet of things (IoT) technology. The programming logic control that is used in the proposed system is consisted of six input from the sensors: namely, potential hydrogen (PH) value, electrical conductivity (EC) value, water temperature value, air temperature value, light value, motion sensor value. All of these values will be communicated to the microcontroller (ESP32) by the sensors. The microcontroller will transmit all the values (data) received through Wi-Fi to the internet on ThingSpeak and Blynk platforms for analysis and visualization.

[11] Hydroponics as an advanced technique for vegetable production: An overview. Various hydroponics structures such as wick, ebb and flow, drip, deep water culture and Nutrient Film Technique (NFT) system, their operations, benefits, limitations, performance of different crops like tomato, cucumber, pepper and leafy greens and water conservations have been discussed.

The type of hydroponics farming technique that is deployed in this experiment, is called nutrient film technique (NFT) for efficient resources management as it allows reuse of nutrient solution. Tomato plant is introduced to the setup for monitoring and control to observe if it will grow well. If the plants grows well, it will be treated as such without further evaluation. Under this arrangement, distance is collapsed, hence monitoring and various regulations can be done from anywhere. Plants like Spinach, Pepper and Lettuce are also introduced to the setup to check if they can grow well using the same formulation.

2.5 Methodology

Methodology is a set of standardized procedures, technical approaches, management techniques and documentation used to carry out the functions of a project.

Research methodology is the qualitative or the quantitative technique through which facts (data) and figures are collected, analyzed and implemented about an object.

The choice of the research methodology for this research task, is based on the objective of the research tasks. Which is to innovate an automation model using mobile/web application that will ensure operational efficiency in hydroponics agriculture based on internet of things technology (IoTT) and system development life cycle (SDLC).

2.7 The Design of the Proposed System

This proposal will be executed using computational approach. Therefore, the design is broken down into two units. Namely: Hardware and Software units respectively.

2.8 Hardware

The hardware is the collection of all the physical components of the system working together for a common goal. These includes the, ESP 32 microcontroller which serves as the brain module of the automation model, peripheral sensory devices such as: temperature and humidity sensor, potential hydrogen (pH) sensor, electrical conductivity (EC) sensor, light sensor, water temperature sensor, cooler systems, motion sensor, buzzer, relay, pump components and ESP 32 CAM for the implementation of computer vision.

These sensors are used as data collection agents and communicate to the microcontroller all of these data collected, so that analysis can take place and various decision can be reached interns of resources allocation and utilization for growing plant/crops. We developed hydroponics farming technique testbed, known as nutrient film technique (NFT).

Fig-1: Hardware Components Used

2.9 Software Requirements

Arduino Integrated Development Environment (IDE) is used for coding the application and it runs on Windows operating system. The Programming Language used is C. ThingSpeak Platform is used for the implementation of Internet of Things Technology (IoT) .Blynk Platform is used for the implementation of Mobile application functions. Wi-Fi which is ESP 32 on board built in connects to the external WI-FI and to the internet for data transmission to ThingSpeak and Blynk platforms.

The sensors are programmed for data collection based on predefined values.

For example temperature and humidity values ranges from low (< 26 ^{o}c), high (> 29 ^{o}c). PH values ranges from low (<6.0), high (>7.0). EC value stands on (<=2.0). Light value low (0), high (1). Water temperature values ranges from low (< 25 ^{o}c), high (> 27 ^{o}c) PIR value ranges from Low (0), High (1) respectively. The system includes six (6) sections to control and manage the automatic hydroponics application. ESP 32 microcontroller is used to control the various functions of the system, including temperature and humidity sensors, light sensors, the pH sensor, water temperature, motion sensor and electrical conductivity sensor.

Section 1: To control the air temperature, when the system gets the value from the temperature and humidity sensors, the FAN will be activated in case of the temperature higher than the indicated value.

Section 2: To control the light level, if the turn on - turn off the LED from the board received the value from the light sensor and the intensity of light is lower than the set value, the system will operate relay module to turn on the LED until the intensity is equal to the set value.

Section 3: The pH control is started when the pH value is higher than the set value and the system will release the pH solution until the pH value is lower than the set value.

Section 4: To control the water temperature, the water temperature sensor will send the value received, if the value is as stipulated by the range, no action will be taken, but if the value is outside the range, then the cooler FAN will be activated until the value returns the normalcy.

Section 5: To control the electrical conductivity, the electrical conductivity sensor will have to send the value received to the microcontroller, if the value is normal, no action will be taken, but if the value is outside the range, then the solution nutrient could be replaced,

Section 6: To control intruders, when the motion sensor receives a signal that an object has entered the farm environment, the low signal will return to high signal indicating that an object has intruded by using the sound energy.

2.9.1Choice of Programming Language

Arduino Integrated Development Environment (AIDE). Programming Language used is C. ThingSpeak Platform for Internet of Things Technology (IoT). Blynk Platform for Mobile application. Microsoft Excel for displaying data from the ThingSpeak platform. Fig. 2, shows it.

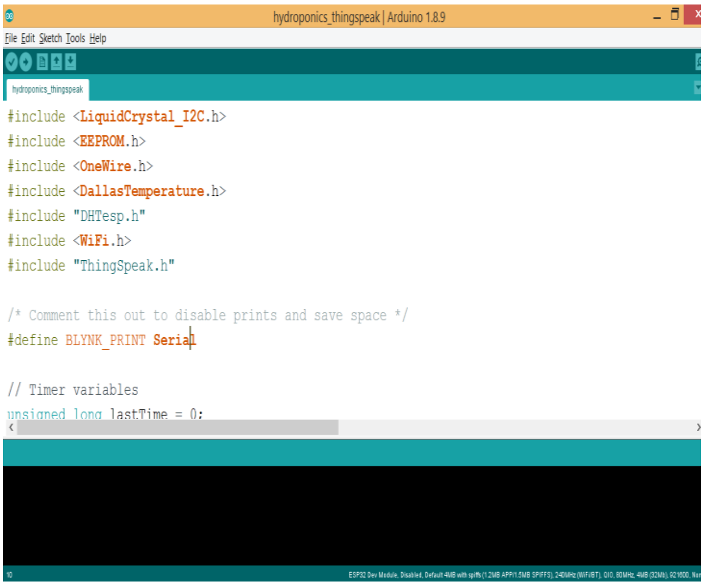

Fig-2: Arduino Integrated Development Environment (AIDE)

2.10 System Implementation

The system implementation of Internet of Things (IoT) Hydroponics Agriculture is shown in Fig. 3. The microcontrollers and the peripheral devices are arranged in a plastic container to make it easier to move and secure it from damages.

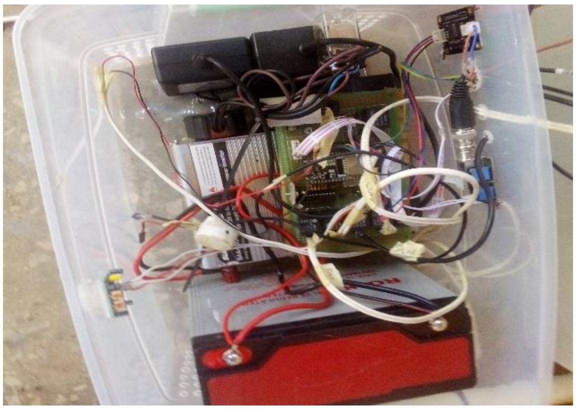

Fig-3: Automation device/Model

1. Potential Hydrogen (PH) sensor is the sensor that is used to measure the PH value of the installation if it is in the normal range. If it is below the normal range, the PH UP will be activated automatically to normalize the range and if it is above the normal range, the PH DOWN will be activated automatically to bring it down to the normal range.

2. Electrical conductivity (EC) sensor is the sensor that is used to measure the nutritional value of the installation, if the EC condition is below the normal range value, it will show in the growth of the plants that, it is malnourished and the nutrient solution will be replaced.

3. Water temperature sensor (DS18B20) is the sensor that is used to collect data about the temperature of the nutrient solution to check if is within the normal range. If the temperature is higher than the determined value, the cooler system will be activated to regulate the temperature to normalcy.

4. Environmental and Humidity sensor is the sensor that is used to measure air temperature in the system installation if it is in the normal range. If it is not within the normal range, the FAN device, will be activated to bring the temperature to the normal range.

5. PIR sensor is the sensor that is used for the detection of saboteurs.

6, Hydro pump is used for continuous supply of solution nutrient to the plants.

7. Relay systems are used for opening and closing of circuit.

8. ESP 32 CAM is used for the implementation of computer vision.

9. ESP 32 functions as a microcontroller that regulates the work of the automation control system.

2.11Material Requirements

PVC components

Gum and connectors

Cutting tool such as saw

A reservoir of 50 liters capacity to contain nutrients solution

Transmission tube to feed the crops/plants with the nutrients solution

PHUP and PHDOWN units

Introduction of 14 units of three varieties of vegetables crops (tomato, lettuce and pepper)

2.12 Nutrients Requirements

Master blend: Nitrogen: 4. Phosphorous: 18. Potassium: 38

Calcium nitrate: 155

Epsom Salt

Mixing the elements in the right proportion (formula)

For solution A

For every 100ml of water, add 15ml of NPK, then add Epsom Salt half of that which is 7.5ml.

For solution B

For every 100ml of water, add 15ml of Calcium Nitrate.

NUTRIENT SOLUTION

Add 4ml of solution A and solution B to 1liter of water. Use the quantity of water you need to get the final nutrient solution. For this experiment, we need 50 liters of water. Fig. 4, shows it.

Fig-4: Nutrient Solution

Fig-5: Seedlings: Tomato, Spinach, Lettuce and Pepper

Fig-6: Nutrient Film Technique Setup (NFT)

VID-20211123-WA0014.mp4

Video: Hydroponics Testbed (Double Click)

2.13 Discussion

After series of testing of the automation system, it was seen that the microcontroller device collected data from all the devices attached to it and transmitted to both Wed/Mobile domains.

2.13.1 Potential Hydrogen (PH) Sensor

Potential Hydrogen sensor successfully collected and transmitted the required data of the solution nutrient to the microcontroller during the series of test conducted. Chart 1, shows PH sensor data.

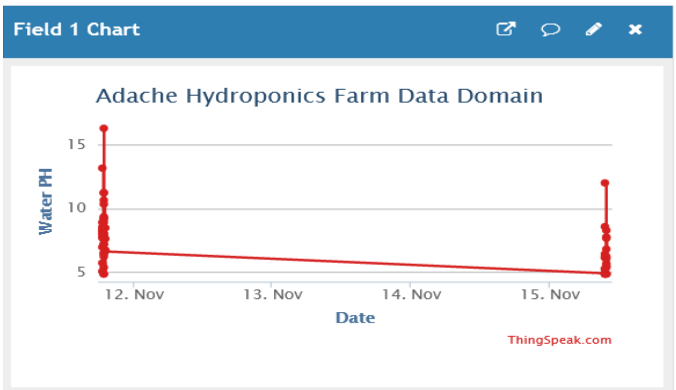

Chart-1: PH Sensor Data

2.13.2 Water Temperature Sensor

Water temperature sensor successfully collected and transmitted the required water temperature data to the microcontroller during the series of test conducted. Chart 2, shows PH sensor data.

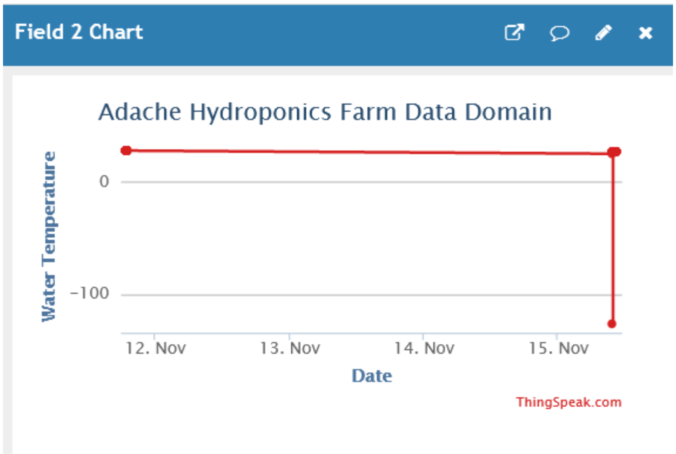

Chart-2: Water Temp. Sensor Data

2.13.6 Atmospheric Temperature sensor

Atmospheric temperature sensor successfully collected and transmitted the required temperature data to the microcontroller during the series of test conducted. Chart-3 shows atmospheric Temp. Sensor Data

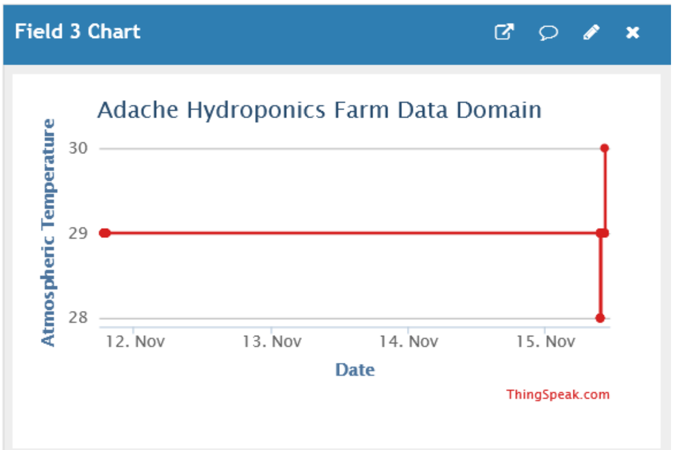

Chart-3: Atmospheric Temp. Sensor Data

2.13.7 Relative Humidity sensor

Relative Humidity Sensor successfully collected and transmitted the required relative humidity data to the microcontroller during the series of test conducted. Chart-4, shows relative humidity sensor Data

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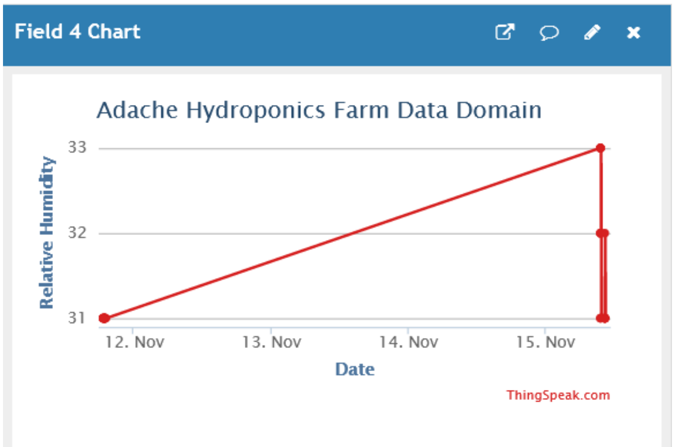

Chart-4: Relative Humidity Sensor Data

2.13.8 TDS

TDS Sensor successfully collected and transmitted the required relative humidity data to the microcontroller during the series of test conducted. Chart 5, TDS sensor data

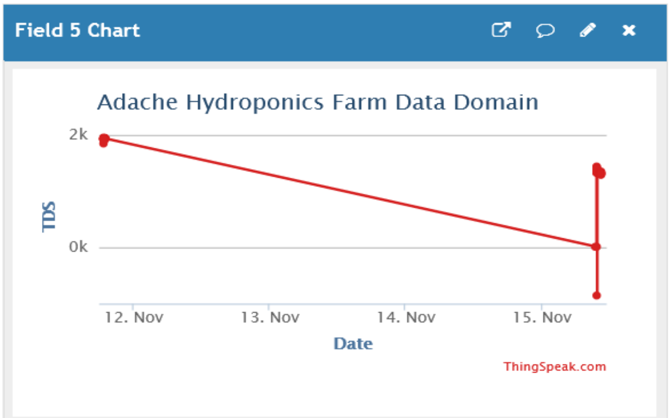

Chart-5: TDS Sensor Data

2.13.3 Electrical conductivity (EC) Sensor

Electrical conductivity sensor successfully collected and transmitted the required data of the measure of the concentration of the nutrient solution to the microcontroller during the series of test conducted. Below is the data chart.

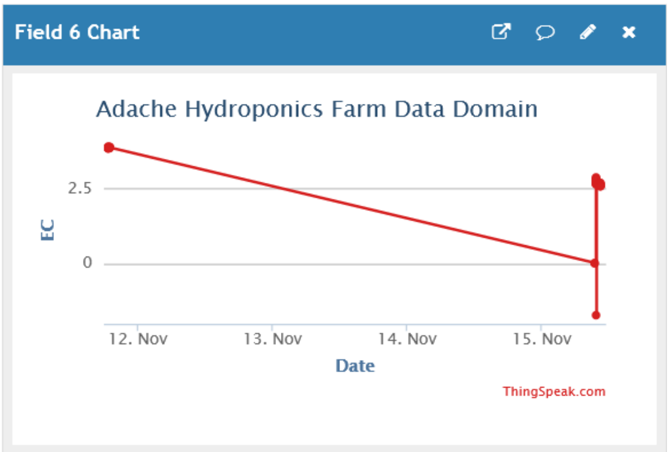

Chart-6: EC Sensor Data

2.13.4 Light Sensor

Light sensor successfully collected and transmitted the required data of the range of light intensity to the microcontroller during the series of test conducted.

2.13.5 PIR Sensor

PIR sensor successfully collected and transmitted the required data about the threat/instances of saboteurs to the microcontroller during the series of test conducted.

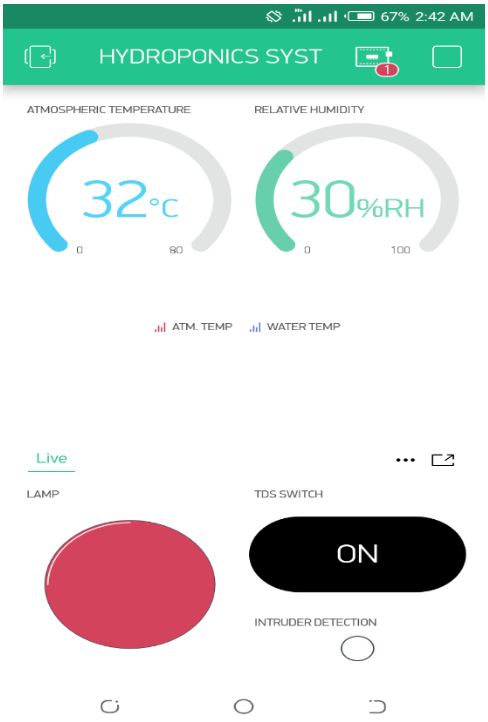

Fig-7: Blynk Domain Data

ESP 32 CAM

ESP 32 CAM successfully collected and transmitted the required data of the growth of the plant to the mobile application domain during the series of test conducted.

2.14 Plants Growth Evaluation

In this research experiment, the researcher did the plant evaluation using the plant growth attribute. The evaluation was done using two approaches: Namely: Visual look and Computer vision technique.

From the visual look, one can see that, the plants height is good. The color of the plants is green. The leave weight and height are very fantastic, an indication that the formula used to grow the plant is very rich. The researcher actually planted four varieties including: Tomato, lettuce, Pepper and spinach to check if all of them can grow together using the same nutrient solution formulation. And from the result, it is clear that they can be grown together using the same formulation because they all responded well. The researcher planted the crops, monitored and controlled them for 6 weeks.

The computer vision used in the implementation of the plant growth evaluation was based on the acquisition and application of ESP32 CAM microcontroller. Below are the pictorial presentation of the plants growth.

Fig-8: Plant Visual Look

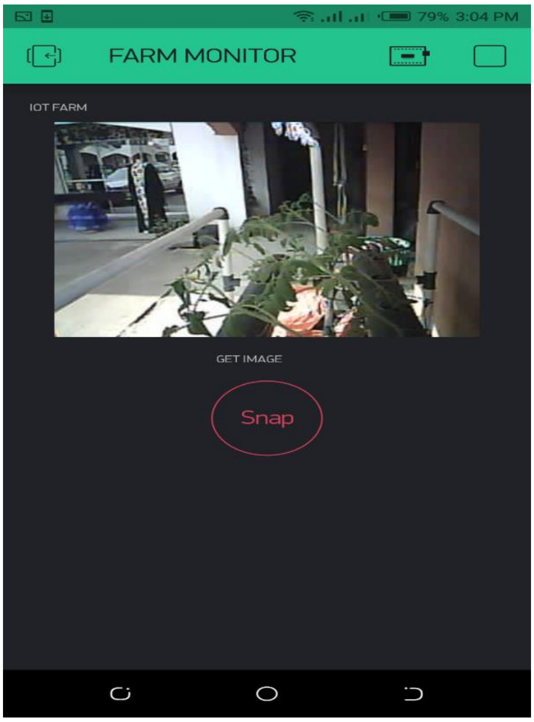

Fig-9: Plant Computer Vision

Conclusion

In this research task, we proposed an Internet of Things Hydroponics Agriculture Using Web/Mobile Applications. The Internet of Things (IoT) technology is used to monitor, control the water and nutrition needs and supply to the plants. The results indicated that, the plants responded well to the nutritional and the environmental parameters that they were placed under for six (6) weeks. The visual looks and the computer vision used as evidence of growth for the plants shows these.

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