IOT BASED SMART PLANT MONITORING SYSTEM WITH AUTOMATED WATERING AND FERTILIZING

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***Abstract*—It is vital in gardening and agriculture to main-tain the plants properly to ensure proper growth and health.Therefore, it is important to continuously monitor whether the plants get water, sunlight, and fertilizers properly. To achieve this "IOT Based Smart Plant Monitoring System with AutomatedWatering and Fertilizing" keeps tracking about important factors surrounding the plants such as soil moisture level, sunlight, humidity, and temperature. By keep tracking above parameters, "IOT Based Smart Plant Monitoring System with Automated Watering and Fertilizing" will be able to automatically water the plants, capable of applying liquid fertilizer automatically under a user-defined time cycle and a horticulture led grow light can also be automatically provided if the system is used in an indoor environment, based on the indoor lighting conditions. Also, these collected sensor data and automated activities can be monitored in real time, manually configured, and operate using a mobile device.**

***Index Terms*—IOT, Plant Monitoring, Automated, Fertilizing, Watering, Automated**

I. Introduction

A. Background information on plant monitoring systems

Plant monitoring systems are used to monitor and maintain the growth and health of plants. These systems use various sensors and data collection techniques to gather information about the plants, such as soil moisture, temperature, humidity, light intensity, and nutrient levels. The collected data canthen be analyzed to determine the plant's needs and to make informed decisions about when to water or fertilize the plant. Plant monitoring systems can be used in various settings, such as greenhouses, indoor plant cultivation, and outdoor gardens. The goal of plant monitoring systems is to provide optimal growing conditions for the plants, which can lead to increased yield and improved plant health. Plant monitoring systemshave become increasingly popular in recent years due to the riseof precision agriculture and the use of technology to op- timize farming practices. IoT-based plant monitoring systems take advantage of the Internet of Things (IoT) technology to enable remote monitoring and control of plants. With IoT- based plant monitoring systems, plant data can be accessedand managed remotely using a smartphone or a computer, allowing for more efficient and effective plant care. Automated watering and fertilizing systems can be integrated into IoT-based plant monitoring systems to provide a fully automated and optimized plant care system.

B. Overview of the proposed IoT-based smart plant monitoring system

An IoT-based smart plant monitoring system is designed to collect and analyze data related to plant growth, health, and environmental conditions. The system typically includes sensors, micro-controllers, and wireless communication devices that are connected to a central control unit or cloud-based platform. The following is an overview of the proposed IoT-based smart plant monitoring system:

- Sensor Devices: The IoT-based smart plant monitoring system typically includes a range of sensor devices that measure various parameters related to plant growth and health, including soil moisture, temperature, humidity, light intensity, and air quality. The sensors may be installed directly in the soil or placed in close proximity to the plants.
- Micro-controller: The sensor data is collected by a micro-controller, which processes the data and sends it to the central control unit or cloud-based platform. The micro-controller may also control other components of the system, such as actuators that control the watering system or fans that regulate temperature.
- Wireless Communication Devices: The IoT-based smart plant monitoring system typically uses wireless communication devices to transmit data from the sensor devices to the central control unit or cloud-based platform. Wireless communication devices may use various protocols such as Wi-Fi, Bluetooth, or Zigbee.
- Central Control Unit/Cloud-Based Platform: The central control unit or cloud-based platform is responsible for receiving and analyzing the data collected by the sensor devices. The central control unit may be a dedicated device or a software platform that runs on a server. The platform may use machine learning algorithms to analyze the data and provide insights into the plant's health and growth.
- User Interface: The IoT-based smart plant monitoring system typically includes a user interface that allows

users to interact with the system and view data related to plant growth and health. The user interface may bea mobile application or a web-based dashboard that displays real-time data and provides notifications when certain parameters fall outside of the desired range.

Overall, the IoT-based smart plant monitoring system provides a comprehensive solution for monitoring and managing plant growth and health. The system allows users to optimize plant growth conditions and respond quickly to any issues that may arise.

C. Importance of automated watering and fertilizing in plant growth

Automated watering and fertilizing are critical factors for healthy plant growth. Here are some reasons why:

- Consistency: Automated watering and fertilizing ensure that plants receive a consistent supply of water and nutrients, which is essential for healthy growth. Consistent watering helps prevent under or over-watering, whichcan stress plants and affect their growth. Automated fertilization ensures that plants receive the right amount of nutrients at the right time, which can improve their health and yield.
- Efficiency: Automated watering and fertilizing can be more efficient than manual methods, especially for large-scale plant production. Automated systems can be programmed to deliver the right amount of water and fertilizer, reducing waste and saving time.
- Precision: Automated watering and fertilizing systemscan be programmed to deliver precise amounts of water and nutrients based on specific plant needs, soil con-ditions, and weather patterns. This precision can helpmaximize plant growth and yield.
- Remote Monitoring: Automated watering and fertilizing systems can be remotely monitored and controlled, allowing for adjustments to be made in real-time. This is particularly important for greenhouse or indoor plant production, where conditions need to be carefully managed.
- Stress Reduction: Automated watering and fertilizing can help reduce plant stress, which can occur when plants are under-watered or over-fertilized. This stress can lead to stunted growth, disease, and even death. Automated systems can help ensure that plants receive the right amount of water and nutrients, reducing the risk of stress.

In summary, automated watering and fertilizing are critical components of healthy plant growth, providing consistency, efficiency, precision, remote monitoring, and stress reduction.

II. Research Objectives

- To explore and identify a mechanism to automate the plant watering process based on soil moisture levels.
- To explore and identify a mechanism to automatically apply liquid fertilizers based on a user-defined time cycle.
- To explore and identify a mechanism to automatically provide artificial horticulture light when there is a lack of natural sunlight.
- To explore and introduce a proper way to inform users about the status of automated activities and allow users to monitor collected sensor data remotely using a mobile device.

III. Literature

With the current situation of the country, the people ofthe society tend to grow vegetables and fruits for their own daily consumption. Furthermore, the questionable quality and high prices of commercially available vegetables and fruits are driving more people to grow their own fruits and vegetables at home. Although this is a positive trend, the problem is many people find it difficult to focus on maintaining andtakingcare of their plantations due to their busy lifestyles. Currently, most people apply water and fertilizer to their cropsmanually, which is a time-consuming and labor-intensive task.As a resultof these reasons, people are tempted to abandon their crops, there are some existing solutions to this problem, but they are ineffective for a variety of reasons, such as lack of remote control, no centralized control, limited data provision to users, poor upgrade-ability, inability to use in all cultivationenvironments (indoor, outdoor, garden). Furthermore, mostsystems do not provide artificial lighting and do not havean automatic fertilizer application function. A solution “IoT Based Smart Plant Monitoring System with Automated Water-ing andFertilizing” was designed. Several sensors, includinga soil moisture sensor, a humidity and temperature sensor,and anLDR sensor, were used to implement this system to accomplish the main objective of automating the plant maintenance process to ensure the healthy growth of plants with minimal human interaction.

A. Review of related studies on plant monitoring systems

Plant monitoring systems have become increasingly popular in recent years, as they provide a convenient and efficient way to monitor the health and growth of plants in various settings, including indoor and outdoor environments. In this literature review, we will discuss some of the key findings from previous studies on plant monitoring systems.

- Plant monitoring using sensors One of the most common methods of plant monitoring is through the use of sensors. These sensors can measure various environmental factors that can affect plant growth, such as temperature, humidity, soil moisture, and light levels. In a study publishedin the Journal of Agricultural Science and Technology, researchers used a wireless sensor network to monitor soil moisture, temperature, and humidity in a greenhouse environment. They found that the system was effective in providing real-time data on plant growth and could be used to optimize irrigation and fertilization practices.
- Plant monitoring using machine learning Machine learning algorithms have also been used in plant monitoring systems to analyze sensor data and provide insights into plant health and growth. In a study published in the journal Sensors, researchers used machine learning al- gorithms to analyze data from a greenhouse environment

and predict plant growth based on environmental factors such as temperature, humidity, and light levels. They found that the system was effective in predicting plant growth and could be used to optimize growing conditions.

- Plant monitoring for precision agriculture Plant monitoring systems are also being used in precision agriculture, where they can help farmers optimize crop yields and reduce resource waste. In a study published in the Journal of Agricultural Engineering Research, researchers developed a plant monitoring system using drones to capture images of crops and analyze them using machine learning algorithms. They found that the system was effective in identifying areas of crops that needed more water or nutrients and could be used to reduce resource waste.
- Plant monitoring for urban agriculture Plant monitoring systems are also being used in urban agriculture settings, where space is limited and resources are scarce. In a study published in the Journal of Urban Technology, researchers developed a plant monitoring system using sensors to monitor soil moisture, temperature, and humidity in an urban rooftop garden. They found that the system was effective in providing real-time data on plant growth and could be used to optimize growing conditions in urban agriculture settings.
- Plant monitoring for research purposes Finally, plant monitoring systems are also being used in research settings to study plant growth and development. In a study published in the journal Plant Methods, researchers developed a plant monitoring system using a high-throughput phenotype platform to measure various plant traits, such as leaf area, stem height, and chlorophyll content. They found that the system was effective in providing high-quality data on plant growth and could be used to study plant responses to various environmental factors.

Overall, plant monitoring systems have become increasingly popular in various settings, and they offer many benefits, including real-time data on plant growth, optimized growing conditions, and reduced resource waste. Further research is needed to optimize these systems and explore new applications in plant monitoring.

B. Overview of IoT-based systems in agriculture

IoT-based systems have been gaining popularity in the agriculture industry, as they offer a range of benefits such as increased efficiency, improved crop yield, reduced waste, and better resource management. These systems rely on anetwork of connected sensors and devices that gather data about various aspects of farming operations and transmit itto a centralized platform for analysis and decision-making. Here are some examples of IoT-based systems in agriculture:

- Precision agriculture: This system uses sensors, drones, and other IoT devices to collect data on soil moisture, temperature, pH levels, and other environmental factors. This information is used to optimize crop growth and reduce resource waste, such as water and fertilizer.
- Livestock monitoring: IoT sensors can be used to monitor the health and behavior of livestock, such as tracking their movements, feeding habits, and vital signs. This helps farmers detect early signs of disease and take preventative measures.
- Supply chain management: IoT-based systems can help farmers and food processors monitor the temperature, humidity, and other conditions of food products as they move through the supply chain. This helps ensure that products are transported and stored properly, reducing waste and spoilage.
- Automated irrigation systems: IoT sensors can be used to measure soil moisture and weather conditions, triggering automated irrigation systems when necessary. This helps farmers conserve water and reduce the risk of overwatering.
- Farm equipment monitoring: IoT sensors can be installed on farm equipment such as tractors and harvesters to monitor performance and detect maintenance issues before they cause breakdowns. This helps farmers reduce downtime and increase productivity.

Overall, IoT-based systems offer a range of benefits to farmers and the agriculture industry as a whole. By gathering and analyzing data in real time, these systems can help farmers make better-informed decisions, improve efficiency, and reduce waste.

C. Discussion of automated watering and fertilizing systems in plant growth

Automated watering and fertilizing systems in plant growth are a type of IoT-based system that uses sensors and controllers to automate the process of providing water and nutrients to plants. These systems offer a range of benefits to farmersand plant growers, such as improved efficiency, reduced labor costs, and better crop yields. Here are some key points to consider when discussing automated watering and fertilizing systems:

- Watering: Automated watering systems use sensors to measure soil moisture levels and adjust the water supply accordingly. This helps ensure that plants receive the right amount of water at the right time, reducing the risk of overwatering or under-watering. Some systems use drip irrigation, which delivers water directly to the roots of plants, reducing water waste and evaporation.
- Fertilizing: Automated fertilizing systems use sensors to measure the nutrient levels in the soil and adjust the fertilization accordingly. This helps ensure that plants receive the right amount of nutrients at the right time, improving their growth and health. Some systems use fertigation, which combines fertilization with irrigation, delivering nutrients directly to the roots of plants.
- Benefits: Automated watering and fertilizing systems offer a range of benefits to plant growers, such as increased efficiency and reduced labor costs. These systems can also improve crop yields by providing plants with optimal conditions for growth. By automating the process of

watering and fertilizing plants, growers can focus on other aspects of their operations, such as pest control and harvesting.
- Challenges: While automated watering and fertilizing systems offer many benefits, they also pose some challenges. These systems require a significant investment in hardware and software, as well as ongoing maintenance and monitoring. They also require a certain level of technical expertise to operate effectively, and growersmay need to adjust their practices to accommodate the new technology.

Overall, automated watering and fertilizing systems are promising technology for plant growers, offering a range of benefits and opportunities for increased efficiency and improved crop yields. By carefully considering the challenges and opportunities associated with these systems, growers can make informed decisions about whether to adopt them in their operations.

IV. METHODOLOGY

This product mainly focused on small scale cultivation environments such as home indoor and outdoor gardens. The "IOT Based Smart Plant Monitoring System with Automated Watering and Fertilizing" is designed to monitor several physical conditions of the cultivation environment and trigger automated functions accordingly. This system utilizes several sensors to accomplish these automated tasks. These sensors collect data of the surrounding environment and send those data to main control unit to process. An Arduino board is used as the main control unit of this system. Arduino units programed to process data that are collected by sensors and trigger automated functions according to those data. Main components that to be used in this system are Arduino uno, two pumps for water and liquid fertilizer, RTC module, Wi-Fi module, LED grow light, soil moisture sensor, LDR sensor, temperature and humidity sensor, water level sensor. This system utilizes these components and sensors to achieve the aforementioned automated functions. All these operations are expandable to meet user requirements and adapt to the cultivation environment.

A. *Automatic plant watering process*

Water is an essential component for the existence of a plant and in cases where the plant cannot get the water it needs from natural sources, it is essential to provide the water needed by the plant from external resources. Especially when plants are grown in indoor environment there should be an external resource to water the plants. Therefore "IOT Based Smart Plant Monitoring System with Automated Watering and Fertilizing" employs a soil moisture sensor to automate the watering process. The system capable of collecting the data about moisture level of the soil using soil moisture sensor. Then the Arduino unit process that data, if the moisture levels below preferred lower level, it will trigger water pump that attached to the water tank and supply water for the plants. There is a water level sensor in the water thank to detect the

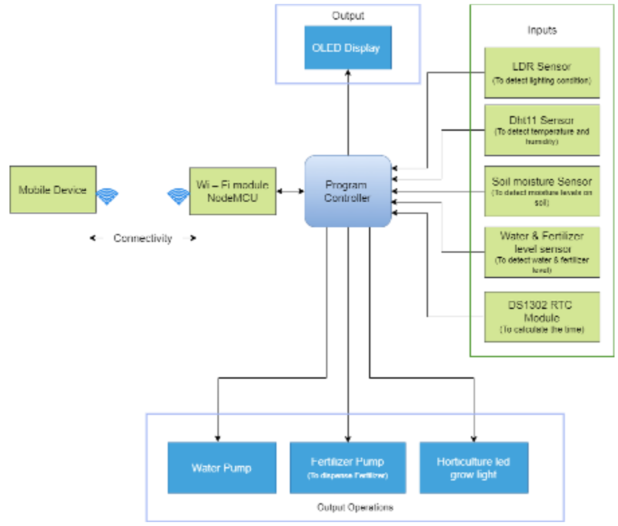

Fig. 1. System Diagram

water levels inside the tank and system will notify the user about available water levels through connected mobile device. So, the user can refill the water if needed.

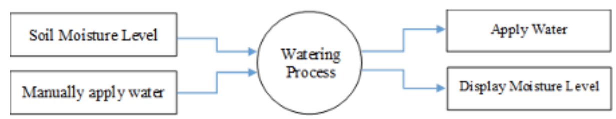

Fig. 2. Watering Process

B. *Automatic liquid fertilizer dispense process*

As well as watering the plant applying fertilizers is very important to maintain good crop and increase yield. Also, it increases the nutrient level of the soil and helps the plants to grow properly. To accomplish this task, the system uses a liquid fertilizer dispense module that can automatically distribute liquid fertilizer to the plants. The Arduino unit is programmed to release the liquid fertilizer in a given time cycle to automate the fertilizer dispensing process using the RTC module. This period can be set by users according to their application.

- Do not apply fertilizer
- Apply fertilizer once a week
- Apply fertilizer twice a week
- Apply fertilizer monthly

To calculate this time periods, the proposed prototype employs DS1302 RTC module (Real Time Clock). When the user-defined time period elapses, the liquid fertilizer pump automatically turns on and distributes the liquid fertilizer to the plants. Additionally, the user can control the amount of fertilizer dispensed by the fertilizer dispensing unit and the user can also operate the liquid fertilizer pump manually in order to apply liquid fertilizer to plans in any case. Also, there is a liquid level sensor implemented in the fertilizer tank to detect the liquid level available in the tank and it allows the system to notify the user about the available liquid fertilizer level through a connected mobile device. This unit is also designed under the modular concept, which allows users to attach or detach the fertilizer dispense unit as per their requirements.

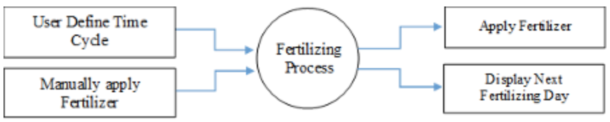

Fig. 3. Fertilizing Process

C. Applying artificial lighting (LED grow light) depend on surrounding lighting conditions

Sunlight is also an essential component for the existenceof a plant [7]. This system utilizes LED grow light moduleto automatically provide artificial lighting when LDR sensor detect low light condition during the daytime. This lighting function is specially designed for environments that lacking natural sunlight or use in an indoor environment. If this unit is not needed, it can be easily removed from the system.

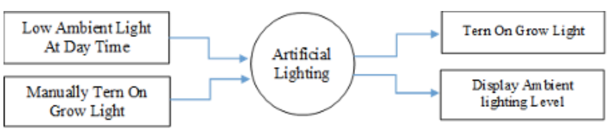

Fig. 4. Artificial Lighting

D. Display details on OLED panel

There is an inbuilt OLED display that used to display all the operations happening such as watering, dispense fertilizer, artificial lighting. Also, this same display is used to showsensor collected data such as temperature and humidity levels, soil moisture level, liquid levels of water and fertilizer tanks. By knowing these details user can take necessary actions to ensure optimal conditions for the plants and system.

E. Mobile device connectivity

Mobile devices can be connected to the system via Wi-Fi connectivity by using the Wi-Fi module (NodeMcu). This enables user to monitor, configure, and control all the automated activities in real time using their mobile device and enable user to control the system from anywhere in the world with less time and effort. Furthermore, user can view all the sensor collected data such as water and fertilizer levels of the tanks, temperature and humidity levels, moisture levels of the soil, and surrounding lighting conditions.

V. IMPLEMENTATION

The system is built on a modular concept, which allows the system to be implemented in different configurations based on user requirements. Therefore, user can easily add or remove several modules depending on their environment and the types of crops they want to grow.

A. Module 1 : Base Module

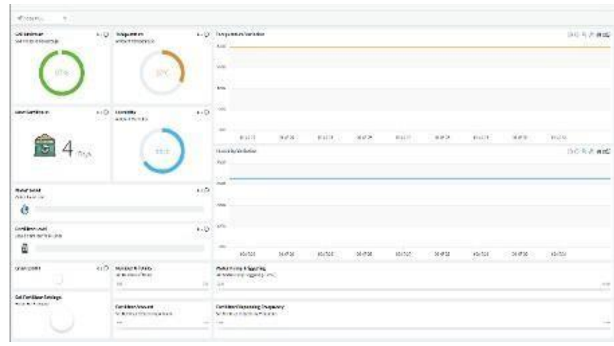

Fig. 5. Web based application

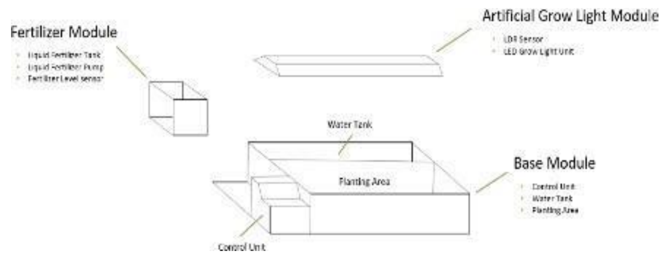

Fig. 6. Modular Concept

B. Module 2: Base module with fertilizer module

C. Module 3 : Base module with grow light module

D. Module 4 : Base module with fertilizer and grow light modules

VI. TESTING AND EVALUATION

A. Test Case 1 – Testing and calibrating soil moisture sensor.

Ther is two types of soil moisture sensor are available on the market to measure moisture levels on soil capacitive soil

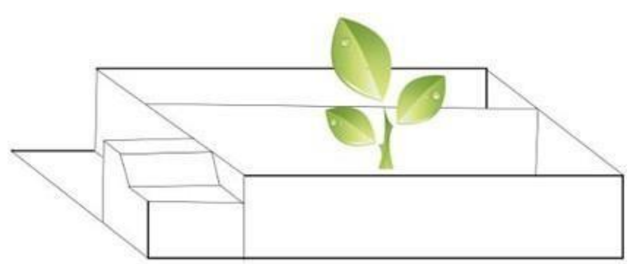

Fig. 7. Base Module

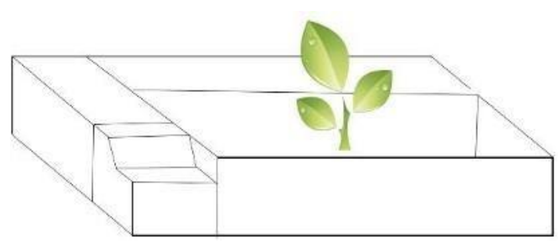

Fig. 8. Base module with fertilizer module

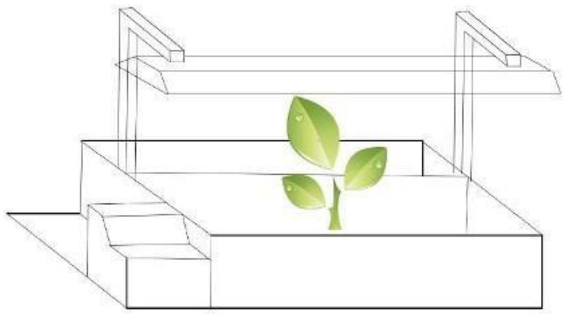

Fig. 9. Base module with grow light module

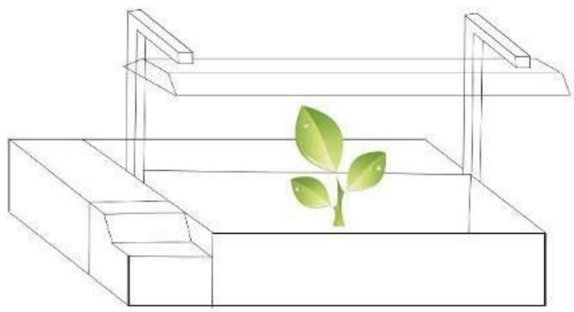

Fig. 10. Base module with fertilizer and grow light modules

moisture sensor and resistive soil moisture sensor. This system utilizes capacitive soil moisture sensor. Both of these sensors need be calibrated before using on application. In calibration process it need to get get output readings of the soil moisture sensor when it is in fully dry (Low level) and fully wet (High level) conditions.

- Fully dry conditions (Low level) - Get output reading when sensor is completely dry while without adding water.
- Fully wet conditions (High level) – Dip the sensor in cup of water and take output reading.

After obtaining these highest and lowest level readings thenall the values between these two readings levels should be converted to express them as a percentage and determine the soil moisture ranges - low, mid and high levels. After calibrating the soil moisture sensor, it was test in several soil samples that is in different moisture levels.

B. Test Case 2 - Testing liquid fertilizer dispenser unit

Liquid fertilizer dispenser unit is designed as separate module that can be add or remove based on user's requirement. Fertilizer dispenser is activated in periodically that has been configured by user. Also, the user can set the amount of fertilizer to be released from the fertilizer dispensing unit. Fertilizer dispenser unit was tested under all of above configurations to ensure the that the timer will trigger the water pump correctly.

- Test the attaching and detaching mechanism of the liquid fertilizer dispense module.
- Test the system by setting the fertilizer dispenser cycle to once a week, twice a week and monthly.
- Monitor the output of the liquid fertilizer level sensor by emptying the liquid fertilizer from the tank.

C. Test Case 3 – Testing artificial lighting (led grow light) unit

This unit also is designed as separate module that can beadd or remove based on user's requirement. This module is designed to provide artificial light using led grow lightwhen LDR that implement in the system detected low lighting condition during the day time it will automatically tern on the grow light. So, system was tested during the day and nighthow it is work under low lighting condition.

- Block the light falling on the LDR and check if the LED grow light turns on during the day.
- Also doing the same process during the night and check if the LED grow light behave the same or not.
- Test the attaching

D. Test Case 4 - Testing temperature and humidity sensor

DHT 11 sensor is used to measure temperature and humidity surrounding the plant [5].

Testing temperature sensor

- To test the temperature sensor, connect DHT11 sensor to Arduino board and place it in a sunny or warm environment little while to read high temperature values and compare these readings with a thermometer reading under same environment conditions, also to read low temperature value by placing DHT11 sensor in cold environment and compare these readings with a thermometer reading.

Testing humidity sensor

- To test the humidity sensor, connect DHT11 sensor to Arduino board and simply blow air through the mouth to the DHT11 sensor then check the output readings of the sensor accordingly (The humidity value will increase).
- Also, the sensor can keep it in a sunny and dry place and get low humidity level readings. As well as keep it in closed indoor environment and spray water to the surrounding air then get high humidity level readings to test the humidity sensor.

E. Test Case 5 – Testing the prototype model under real world scenario

Before finalize the product, system was tested under real-world scenario by interconnecting all the modules together and closely observed how each module behaves individually. Also evaluate the compatibility between the modules and how they interact with each other. Since this is the last stage of testing prototype model was tested in a reasonable time period (Two weeks) under various environmental conditions by growing chili plants.

- Connect all sensors and modules to the main controller board (Arduino UNO)

- Plant crops using suitable soil
- Fill both water and liquid fertilizer tanks with water and liquid fertilizers
- Evaluate the system under all configurations and various environmental conditions
- Observe how the system behaves under all the above settings
- Conduct further development and testing if needed by monitoring test results

VII. CONCLUSION

“IOT Based Smart Plant Monitoring System with Automated Watering and Fertilizing” is ideal for people with busy lifestyles and anyone who interested in growing their own fruits, vegetables, and other crops. This system can also be applied in indoor or outdoor environment. It is design by combining several sensors that capable of sensing several physical factors surround the plants. Furthermore, the modular design approach adopted to design the above prototype enables the user to customize the system according to their preferences. Also, this system is capable of notifying users about automated functions and allowing users to monitor all the collected sensor data and automotive activities remotely using mobile devices. This prototype is designed to meet all the above mainand sub objectives by integrating several automated functions to increase the productivity of the plantation and automatethe cultivation process by minimizing human interaction and helping to overcome the difficulties that the user face in cultivation with their busy lifestyle. Also, these automated functions are activated with minimal human interaction to meet high productivity. Besides that, users are able to manually operate all of these automated activities using a mobile device. By employing this proposed system, the user can save money while consuming locally grown, fresh, safe and healthy fruits and vegetables. Also, this product is developed to meet important factors such as low power consumption, minimum maintenance, and low cost. As a result, the ”IOT Based Smart Plant Monitoring System with Automated Watering and Fertilizing” has been successfully planned and constructed. It was created by combining the features of all of the hardware components used. Every module’s presence has been carefully considered and positioned, resulting in the best possible operation of the unit. The system was thoroughly tested to ensure that it will work properly and reliably.

VIII. FUTURE WORK

Rewrite future works

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