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AUTOMATED ENVIRONMENTAL MONITORING SYSTEM FOR GREENHOUSE FARMING: DESIGN AND IMPLEMENTATION OF A SMART FARMING ROBOT

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Abstract—Incorporating smart technology in agriculture has become crucial for maximizing crop output and resource management, especially in controlled conditions like greenhouses. Since crops, vegetables, fruits, and pest infestation are all impacted by climate change, agricultural output is a top priority for most nations. a creative method of managing greenhouses by creating a clever agricultural robot. With data-driven insights driving sustainable practices and higher crop yields, precision agriculture is made possible by the system's capacity to recognize and react to environmental circumstances. Farmers may enhance indoor cultivation by means of climate control and lessen the detrimental impact of mosquitoes on plants by utilizing innovative technologies such as sensors and controls within greenhouses.In order to effectively oversee croplands and greenhouses nowadays, farmers need to implement Industry 4.0 technology, such robots and Internet of things devices. In this situation, the use of sensors is essential for gathering information and data that will aid in the farmer's decision-making. This research provides a fully autonomous machine that travels through conservatory crop paths with pre-planned routes and can gather environmental data from a sensor network that is wireless in situations when the farmer lacks prior crop knowledge. This robot is a viable alternative for small farms. Lastly, an application is made to assist farmers in planning the robot's path and distance while gathering data from the instruments in order to monitor crop conditions.

Keywrds – Arduino UNO, Wireless Communication, IOT(Internet of Things), Greenhouse, Robot, Farmers, Sensors..

I. INTRODUCTION

The agricultural sector has experienced a transition towards intelligent and mechanized methods to improve output and effectiveness. Maintaining ideal environmental conditions is especially important for greenhouse farming, since it guarantees crop health and productivity. Conventional monitoring techniques frequently fail to deliver the comprehensive and real-time data required for accurate decision-making. Precision agriculture, or smart farming, makes use of contemporary technology like sensors, robots, IoT (which stands for Internet of Things), and computerized processing to maximize crop yields. Reducing the negative effects on the environment while increasing farming's cost-effectiveness, sustainability, and efficiency is the aim. Environmental monitoring is an essential component of smart farming, especially in confined settings like greenhouses. Robotics and sensor technology integration provides potential options for smart agricultural applications to solve these issues.An important advancement in agricultural technology is the creation of a smart farming robot that is tasked with identifying and keeping an eye on the environmental circumstances within a greenhouse. The goal of this project is to design and build a robotic system with sensors that can measure important variables including humidity, temperature, soil moisture, CO2 levels, water level, and ultrasonic sensor. Without the need for human assistance, the robot will allow farmers to obtain important insights regarding the growing surroundings by exploring the greenhouse on its own and gathering data. The design, completion, and assessment of the robotic system will be covered in depth in the following sections. The hardware ingredients, sensor integration, movement algorithms, and data processing techniques used will all be covered.The implementation of intelligent agricultural robots has the potential to significantly transform greenhouse management techniques by enabling data-driven decision-making, streamlining resource allocation, and eventually enhancing crop productivity and quality. Our goals in doing this initiative are to further sustainable agricultural methods and precision agriculture.

1. Importance of Environmental Monitoring in Agriculture

Farmer support for maintaining ideal plant development conditions comes from environmental monitoring. It is possible to continually monitor and modify elements like as air humidity, temperature, light intensity, and moisture levels in the soil to guarantee that plants grow in the best possible circumstances. Efficient resource management is made possible by environmental condition monitoring. Environmental sensors are able to identify minute variations or abnormalities in the surroundings that might point to illness, insect infestations, or stress on plants. Early identification minimizes crop losses and lowers the need for treatment with chemicals by enabling timely action. A great deal of data is produced by environmental monitoring, which may be evaluated to help in decision-making. Utilizing historical data may help with trend identification, crop cycle optimization, and general farm management strategy improvement. Environmental monitoring that is astute encourages sustainable agricultural methods by cutting down on resource waste and decreasing the usage of chemicals.

2.Role of Robotics in Environmental Monitoring

Robotics is essential for automating data gathering and processing in the context of a smart agricultural robot intended for greenhouse monitoring. Sensor-equipped robots may move through greenhouse settings and collect data in real time on the temperature, humidity, light, soil, and health of the plants. This automation allows for continuous monitoring without the need for human intervention while also lowering labor expenses. Agriculture will change as a result of the incorporation of smart agricultural technology, such as robots and environmental monitoring systems.

II. LITERATURE REVIEW

Malende, W. F., Krishna, K. L., Silver, O., and Anuradha, K. (2017, Feb). Use of the Internet of Things to construct a smart agriculture system. A unique Internet of Things (IoT)-based wireless mobile robot is created and put into use to carry out a variety of tasks in the field. This suggested wireless robot has a number of sensors installed to measure various aspects of its surroundings. Hardware for the Raspberry Pi 2 version B is also included to carry out the entire procedure. This innovative intelligent wireless robot's primary capabilities include its ability to sense wetness, frighten birds and animals, spray pesticides, move forward or backward, and turn on and off an electric motor. A wireless camera is installed on the robot to provide real-time activity monitoring.After testing the suggested wireless mobile robot in the field and monitoring its readings, good results were seen. These findings suggest that the system has a great deal of potential for application in smart agricultural systems.

Gordillo-Gordillo, C. A., Rosero-Montalvo, P. D., and Hernandez, W. (2023). A smart agricultural robot that can identify the greenhouse's environmental conditions. Since crops, vegetables, fruits, and pest infestation are all impacted by climate change, agricultural output is a top priority for most nations. Professional farmers therefore have the problem of attaining optimum production outcomes, and they view greenhouse as a very good choice to ensure these results. In this situation, the use of sensors is essential for gathering information and data that will aid in the farmer's decision-making.This research provides a fully autonomous robot that travels through greenhouse agricultural paths with pre-planned routes and can gather environmental data from a wireless network of sensors in situations when the farmer lacks prior crop knowledge. This robot is a viable alternative for small farms.

In February of 2022, Chakraborty, A., Islam, M., Dhar, A., and Hossain, M. S. Precision farming technology uses an IoT-based greenhouse environment monitoring system and smart watering system. The production of food for agriculture in recent decades has been drastically impacted by a number of crucial factors, including soil erosion, population explosions, water shortages, lack of cultivated land, and changes in the climate like global warming. The farming sector may become more productive and of higher quality by implementing IoT and new technology.This study suggests an intelligent use of IoT to provide irrigation and environmental monitoring systems in order to address the present agricultural predicament. The system allows for both on-site and remote (IoT) monitoring of a greenhouse's humidity, soil moisture, temperature, and light intensity. For effective water delivery, an intelligent system for irrigation has also been included. The BLYNK program is used for real-time data monitoring and IoT connectivity. In the event that an issue arises with the smart irrigation system, the IoT system also offers direct control over the water pump.

Mellit, A., Herrak, O., Messalaoui, A., & Benghanem, M. (2021). creation of a cutting-edge deep convolutional neuron network and internet of things-based remote monitoring solution for smart greenhouses.The prototype enables the greenhouse to be equipped with a suitable artificial environment, including water supply, ventilation, intensity of light, and CO2 concentration. With the use of suitable sensors and an inexpensive Wi-Fi module (NodeMCU V3), the regulated parameters (air temperature, humidity level, capacitive soil wetness, brightness of light, and CO2 level) were measured as well as uploaded to a planned webpage thanks to the the internet of things approach. Photographs of the plants were taken using a cheap camera and sent to a webpage for the purpose of classifying and maybe identifying illnesses.In this instance, a Raspberry Pi 4 was equipped with a deep-learning convolutional neural network that A small-scale businesses photovoltaic system was constructed in order to power the prototype. The outcomes of the trial proved the prototype's viability and revealed its capacity to remotely monitor and manage the greenhouse in addition to determining the condition of the plants. Farmers can receive real-time remote sensing and measurement services from the smart prototype that has been created.

In November of 2020, Fernando, S., Nethmi, R., Silva, A., Perera, A., De Silva, R., & Abeygunawardhana, P. W. AI-powered robotically monitored greenhouse agricultural assistance system. Since greenhouses allow farmers to grow plants under regulated climatic conditions and maximize productivity, they play a significant role in modern agriculture.Since greenhouses are typically constructed in regions with subpar climates for plant development, productivity must be increased using artificial setups. Climate factors must be monitored and controlled in order to automate a greenhouse's operations. The ultimate goal of this investigation is to create an automated system that can perfectly regulate and track the environmental variables inside a greenhouse. This will be achieved by using a mobile robot that is connected to the cloud to monitor temperature, humidity, soil moisture, and pH and by using the processing of images and machine learning to identify unhealthy plants. To store acquired real-time data, a database server was developed.

III. METHODOLOGY

Problem Description and Needs the purpose of the initiative is to overcome the difficulties associated with accurately and efficiently monitoring the environmental factors that are vital to plant development and production in greenhouse farming. Manual monitoring techniques that are based on tradition are time-consuming, labor-intensive, and frequently lack real-time data. The objective is to create a smart agricultural robot that can go through a greenhouse on its own, gather information from a variety of sensors, and promptly inform farmers so they can make the best decisions.

A. DHT11(Temperature and Humidity Sensor)

The DHT11 is a computerized moisture and temperature sensor that measures ambient temperature using a thermistor and a capacitive humidity sensor. The sensor converts the capacitance, which varies with the quantity of wetness in the air, into a digital signal. To measure the temperature of the air, the DHT11 also has a thermistor.

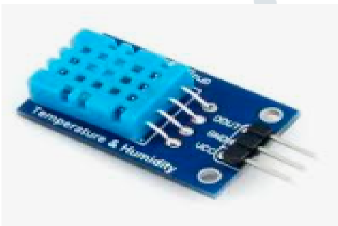

Fig 1: DHT 11 Sensor

The sensor transforms the thermistor's resistance, which varies with temperature, into a digital signal. A single-wire digital communication is used by the DHT11 sensor to connect with the microcontroller (such as the Arduino). It provides the microcontroller with a 40-bit digital input signal that includes checksum information for error detection, temperature, and humidity information. By integrating the DHT11 sensor into a sophisticated farming robot, its capacity to observe and react to environmental conditions is boosted, which benefits crop yield and health in greenhouse agriculture applications.

B. ULTRASONIC SENSORS

Technique for identifying and avoiding barriers in the setting of greenhouses is the application of ultrasonic detection devices in smart farming robots. In order for ultrasonic sensors to function, sound waves must be produced at a frequency greater than that of human hearing. Then, the time it takes voor sound waves to return after striking an object must be measured. The robot can calculate the separations between obstacles and use this information to guide it in the right direction. A burst of sound waves with high frequencies, usually between 20 and 200 kHz, is released by the ultrasonic sensor. The sound waves are released and travel through the atmosphere until they come into contact with a barrier, such a wall, plant, or other structure inside the greenhouse.The sensor calculates how long it takes for sound waves to pass through an obstruction and back.

$$Distance = \frac{Speed\ of\ Speed\ x\ time\ taken}{2}$$

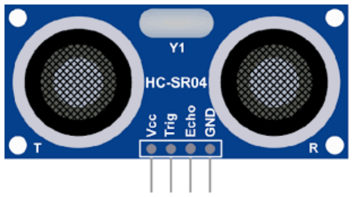

Fig 2: Ultrasonic sensor

The robot's ability to safely maneuver around obstacles like plants, pots, walls as well, or equipment within the greenhouse is mostly dependent on ultrasonic sensors. Real-time obstacle avoidance can be achieved by modifying the robot's trajectory or creating routes free of obstacles based on sensor data. Environmental factors including relative humidity, temperature, and air density can have an impact on ultrasonic sensors, which can therefore have an impact on sound speed and measurement accuracy.

C. WATERLEVEL

The robot's water level sensor is positioned strategically, such next to the base or underside, to maximize water level measurement and reduce interference with other parts. To guarantee correct results depending on the water receptacle or irrigation system of the greenhouse, calibrate the depth of the water sensor. Setting the sensor's maximum mark (full tank) and the starting point (empty tank) is required.

Fig 3: Waterlevel Sensor

This kind of sensor uses variations in capacitance brought on by both the presence or removal of water to determine the water level. The sensor can detect the water level since its electrodes' capacitance varies in tandem with the water level. The water level sensor can tolerate the temperature swings and humidity of a greenhouse since it is sturdy enough. To get accurate water level measurements which are essential for effective irrigation management optimize sensor installation and calibration processes. Greenhouse operators may employ cutting edge technology to optimize crop cultivation techniques and improve irrigation management, which will eventually boost yields and conserve resources. This can be achieved by integrating a water level sensor onto a smart farming robot.

D. SOILMOISTURE

An essential part of a sophisticated farming robot intended for conservatory or agricultural uses is a soil moisture sensor. Its main job is to determine the soil's moisture content, which gives important information that affects both irrigation schedules and the general health of plants. Different concepts can be used by soil moisture sensors to determine the moisture content. Frequency domain sensors, capacitive sensors that are and resistive sensors are common varieties. The soil's dielectric constant varies with moisture content, causing variations in capacitance, which the sensor then measures. The intelligent farming robot can keep an eye on the moisture content at various spots in the greenhouse thanks to the soil moisture sensor. In order to optimize irrigation systems and comprehend the regional variability of soil moisture, this data is crucial.

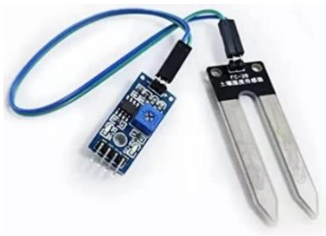

Fig 4: Soil Moisture Sensor

A smart farming robot's ability to monitor plant health, control irrigation, and make decisions is greatly aided by the data that the sensor for soil moisture provides. Reliable the moisture in the soil sensing capabilities are integrated to improve greenhouse farming operations' sustainability and efficiency, which eventually leads to higher crop yields and less consumption of resources.

E. CO2 levels

For greenhouse applications, integrating a CO2 gas detection device into a smart agricultural robot entails choosing an appropriate sensor, comprehending its operation, and integrating it into the robotic system. Selecting the appropriate CO2 gas monitor is essential for precise and dependable measurement in a greenhouse setting. A type of sensor appropriate for the desired usage (for example, non-dispersive ultraviolet (NDIR) sensors are frequently employed in CO2 measurement because of their excellent stability and accuracy). The sensor offers precise readings across the intended range of CO2 concentrations commonly seen in greenhouses, which is normally surroundings up to 2000 parts per million or more.

Fig 5: Co2 Gas Sensor

A quick reaction time that is necessary for prompt environmental monitoring in order to detect quick changes in CO2 levels. The working basis of CO2 gas sensors, especially NDIR sensors, is infrared absorption. The sensor calculates the fraction of the infrared spectrum absorbed by CO2 molecules to the total quantity of CO2 in the earth's atmosphere. The sensor produces an electrical signal (such as voltage or current) according to the CO2 concentration based on the observed absorption. After deciding on a CO2 gases sensor and learning about its operation, include it into the intelligent agricultural robot system. Attach the CO2 sensor to the microcontroller for single-board computer of the robotic platform by utilizing the proper communication protocols (e.g., analog voltage, I2C, or UART).Greenhouse operators may improve overall crop output and health by optimizing growth conditions and gaining actionable data by adding a CO2 gas monitor into an intelligent farming robot. One essential element of a thorough ecological monitoring system for environmentally conscious agriculture is this integration.

IV. PROPOSED SYSTEM

With the goal to monitor and assess environmental conditions in a greenhouse setting, we design and deploy a smart farming robot that is outfitted with a variety of sensors. Enhancing real-time data gathering, automating environmental monitoring duties, and raising crop health and production overall are the main goals of this study. The intelligent agricultural robot uses path-planning and obstacle-avoidance algorithms to maneuver about the greenhouse on its own.

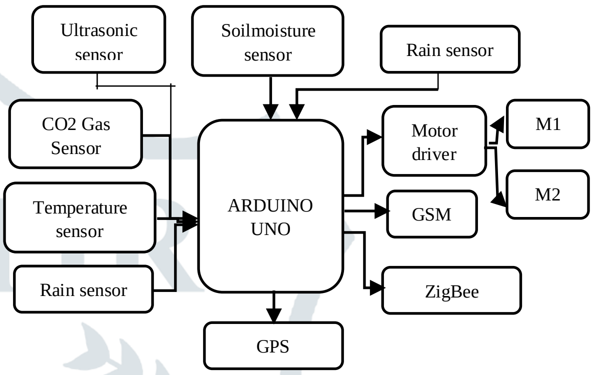

Fig 5: Proposed Block diagram for Smart forming Robot Transmitter side

It possesses sensors to monitor important environmental factors such soil moisture, temperature, humidity, carbon dioxide levels, and ultrasonic sensors. When this robotic system is used, a number of benefits are expected. First off, farmers can deploy resources more effectively as the robot's autonomous operation lowers personnel expenses related to manual monitoring duties. Second, by keeping an eye on the environment constantly, one may respond quickly to changes or abnormalities, which enhances crop quality and lowers waste.

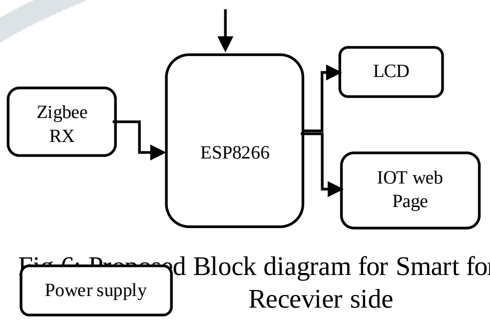

Fig 6: Proposed Block diagram for Smart forming Robot Recevier side

When smart technology is integrated into greenhouse farming, such as robots and sensor networks, there is great potential for sustainable agriculture. Using automation and real-time data, farmers can make smart decisions about lighting, respiration, and irrigation that will save resources and lessen their impact on the environment.

V. RESULTS AND DISCUSSION

An automated environmental monitoring system for greenhouse farming has many notable benefits when integrated with a smart growing robot. The smart farming robot's environmental sensors enable real-time monitoring of key greenhouse parameters, including as the moisture content of the soil, humidity, and sunlight intensity. Using this capability, farmers may constantly monitor the environment from a distance and make adjustments to optimize plant growth. The smart agricultural system provides farmers with the ability to make informed decisions by gathering and analyzing data on environmental elements.

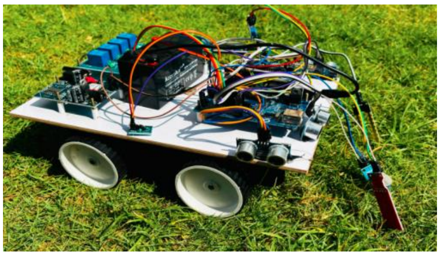

Fig 7: Hardware for Smart forming Robot Transmitter side

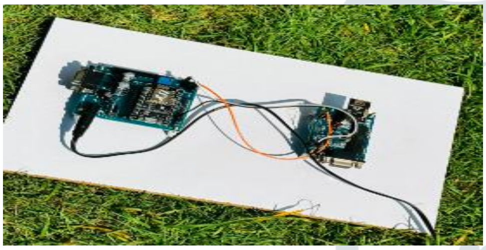

Fig 8: Hardware for Smart forming Robot Recevier side

To maintain ideal growth conditions for various crops, farmers might, for example, automate watering schedules, modify ventilation systems, or use shading tactics depending on the sensor data.

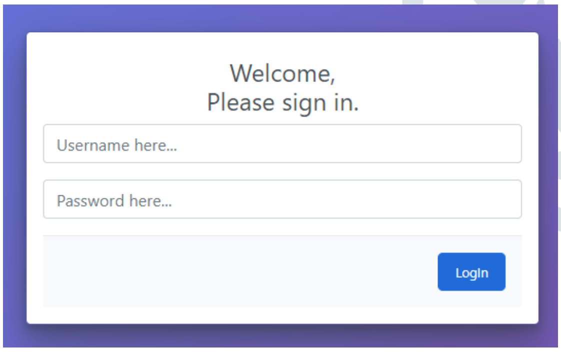

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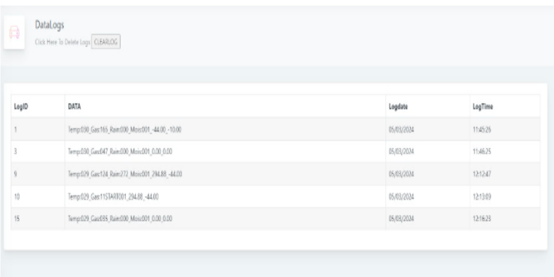
Fig 9 : IOT webPage Login

Plant stress is reduced and growth potential is increased when growing conditions can be adjusted in real time using data from the environment.



DataLogs

Click Here To Delete Logs CLEARLOG

LogID	DATA	Logdate	LogTime
1	Temp:030_Gas:165_Rain:000_Mois:001_-44.00_-10.00	05/03/2024	11:45:26
3	Temp:030_Gas:047_Rain:000_Mois:001_0.00_0.00	05/03/2024	11:46:25
9	Temp:029_Gas:124_Rain:272_Mois:001_294.88_-44.00	05/03/2024	12:12:47
10	Temp:029_Gas:11START001_294.88_-44.00	05/03/2024	12:13:09
15	Temp:029_Gas:035_Rain:000_Mois:001_0.00_0.00	05/03/2024	12:16:23

Fig 10 : IOT webPage Data Log

Early detection of situations that deviate from ideal levels enables the monitoring system to take proactive measures to stop crop diseases, insect infestations, and environmental stressors. The necessity for reactive treatments and crop losses can be greatly decreased by this early detection capabilities. The integration of an automated environmental tracking system with a smart farming robot is a revolutionary step towards environmentally friendly and profitable greenhouse farming.

Fig 11: Graph for greenhouse agri montoring system

VI. CONCLUSION

It shows notable developments in agricultural technology in the type of a smart farming robot. This project used robots and Internet of Things technology to overcome major issues with traditional greenhouse farming practices. With this project, we were able to create a smart growing crops robot that can navigate around greenhouse conditions on its own and gather data in real time on different environmental aspects. Farmers may make well-informed decisions and maximize crop management techniques thanks to the accurate and effective data gathering provided by the integration of sensing for soil moisture, humidity, temperature, and light levels. Proactive intervention made possible by this real-time monitoring capabilities improves crop yields, the effectiveness of resources, and overall farm output. Because the smart agricultural robot operates autonomously, less manual work is required, which lowers labor costs and operating expenses.This feature optimizes workflow efficiency and reduces resource consumption, which supports sustainable agricultural practices. A potential step towards agriculture's future is the integration of an automated surveillance of the environment system with a smart farming robot. This technology has the ability to completely transform greenhouse farming methods by utilizing robots and the Internet of Things to make them more effective, sustainable, and robust to changing environmental constraints.

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