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Smart Farming Robot For Detecting Environmental Conditions In A Green House

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ABSTRACT

Agricultural production is on most countries' national agenda because climate change affects crops, fruits, vegetables, and insect infestation. Therefore, achieving maximum production results is a challenge faced by professional growers, who have seen greenhouses as a very good option to guarantee these results. By using new technologies inside greenhouses, farmers can reduce the damaging effect of insects on plants and improve indoor cultivation through climate control. However, to efficiently manage agricultural fields and greenhouses today, farmers must apply technologies in line with Industry 4.0, such as: robots, Internet of Things devices, machine learning applications, and so on.

In this context, deploying sensors plays a key role in collecting data and finding information supporting the farmer's decision-making. As a feasible solution for small farms, this paper presents an autonomous robot that moves through greenhouse crop paths with previously planned routes and can collect environmental data provided by a wireless sensor network, where the farmer does not have previous information about the crop.

Here, an unsupervised learning algorithm is implemented to cluster the optimal, standard, and deficient sectors of a greenhouse to determine inappropriate growth patterns in crops. Finally, a user interface is designed to help farmers plan both the route and distance to be traveled by the robot while collecting information from the sensors to observe crop conditions.

1- INTRODUCTION

Agricultural production plays a fundamental role in the welfare of society and economic exchange between countries [1]. Therefore, food demand is continuously growing; by 2050, farms will need to produce 70% more than the current years [2]. Nevertheless, some production estimates tell countries that the agriculture sector can produce only 3% more because farmers have postponed seeding several crops on their lands because of climatic changes (e.g., droughts and/or floods) [3]. Furthermore, it also has diminished their profits. Therefore, to counteract undesirable environmental conditions and crops damages because of infestations of insects, in some cases, farmers use fertilizers and pesticides to speed up the sowing and harvesting of crops.

Unfortunately, in some cases they use substances and materials without the knowledge to manage them on a large scale [4]. As a result of the incorrect use of fertilizers and pesticides, the quality of the land decreases as well as the crops cultivated on it (e.g., fruits and vegetables, among others) lose essential nutritional properties [5]. In this context, greenhouses are considered an appropriate choice to maintain environmental conditions within a desirable range. This prevents crops from being exposed to uncontrolled external factors and yields much better harvesting results [6]. However, inhomogeneous and uncontrolled conditions inside a greenhouse can cause it to fail. Furthermore, ensuring the uniformity of the climate is an important issue since greenhouses have areas drier or more humid than others, and irregular soils.

What is worse, differences in the type of irrigation and geographical location, added to the problems mentioned above, can make the greenhouse unprofitable [7]. Moreover, if the farmer lacks sufficient experience, his work, while carrying out the crop management process, could be liable to err [8]. For this reason, accurate and efficient monitoring and automation are keys to turning a failed greenhouse into a profitable one. Having said this, to avoid the above-mentioned concerns, advanced technologies have been introduced in the agriculture sector to make it more efficient and manageable [9].

These technologies have brought novel solutions that both reduce and optimize the use of fertilizers and pesticides [10]. Among these technologies, the Internet of Things (IoT) stands out. In short, IoT is well worth using because it allows the connection among sensors, machines, and humans. Besides, IoT constitutes the foundations of smart farming, merging emerging technologies with machine learning (ML) applications. Nevertheless, smart farming requires several on-site or remote sensors to collect data and find patterns that humans cannot recognize by themselves. Wireless sensor networks (WSN) traditionally deploy sensors in situ to gather crop data.

However, this rigid electronic design requires checking the batteries constantly, and WSN nodes can be damaged when farmers work near them [4]. The above justifies the need to apply flexible remote sensing techniques using autonomous robots, because unmanned aerial vehicles (UAVs) have to face many problems to fly inside indoor environments [9]. In fact, autonomous robots can move through crop lines collecting data while traveling along planned routes. In addition, they can acquire data in specific hours, return to their initial point to recharge batteries, and check the current performance of sensors.

However, they have to deal with extreme scenarios when moving on certain wet or uneven grounds. This harsh environment could inject noise and drift to sensors when they are collecting data. Besides, due to erroneous readings of sensors, sensors wear, and unpredictable events, this could be a non-easy task to detect/remove them. This task is traditionally carried out in powerful servers allocated far away from the greenhouse. As a result, this fact brings about an open communication challenge, because greenhouses are usually placed outside cities and do not have high-bandwidth wireless-communication channels to send the information. Additionally, this procedure of storing information remotely consumes energy in WSN nodes.

Furthermore, working with robots requires a robust central node to coordinate, plan routes, and reprogram tasks. Therefore, farmers need to deal with managing these existing technologies rather than manual tools. Lastly, the robot itself cannot collect data, because it needs sensors.

This brings about another concern to synchronize/prioritize tasks into the microcontroller. This research is focused on developing an ML application that works with an autonomous robot, which collects data from crops in a small-medium-scale greenhouse, on showing farmers relevant information on changes in environmental conditions to support decision-making. This is done to detect specific areas inside a greenhouse where crops do not grow in optimal conditions. The above-mentioned autonomous robot has two well-defined subsystems and planned routes to reach an unsupervised ML application in a decentralized network where the greenhouse lacks a stable internet connection.

The first subsystem collects data with information on the greenhouse's environmental conditions and sends them to a central node by Lora Wan protocol. The second subsystem is in charge of the design and control of the robot to guarantee its correct performance while it moves through planned crop routes. To achieve this, a proportional- integral derivative (PID) controller controls the DC motors that regulate the robot's movement. The PID controller is designed so that the robot can move over uneven terrain and in harsh environments, traveling at low speed along crop lines and without losing the grip provided by the chassis and tracks. All the information is stored in a central node in charge of training unsupervised algorithms since farmers do not have previous knowledge of the crops.

The results are presented in a graphical user interface (GUI) without exchanging information with the cloud or big servers. The farmer can plan the robot route and traveling distance on this GUI, before taking each data acquisition sample and observing crop conditions. In addition, to compare the farmer's decision-making, the robot has a trained model to detect inadequate environmental conditions in real-time monitoring. Consequently, this local decision allows double-checking with the farmer's experience to make future decisions. As the main results of this research, the k-means algorithm is defined as the unsupervised machine learning algorithm to build three clusters.

Proposed System

The proposed system introduces a smart farming robot equipped with advanced sensors to autonomously detect and monitor environmental conditions in a greenhouse. It can analyze data in real-time, adjust conditions automatically, and provide insights to optimize plant growth and resource usage.

The proposed system is a smart, mobile farming robot designed to monitor and manage environmental conditions within a greenhouse to support precision agriculture. This robot will be equipped with multiple environmental sensors to measure parameters such as temperature, humidity, soil moisture, light intensity, and CO2 levels. A microcontroller (e.g., Arduino or ESP32) will serve as the central control unit, collecting data from the sensors and processing it in real time. The robot will also be capable of autonomous movement using motor drivers and navigation sensors (like ultrasonic sensors or IR sensors) to move between rows of crops while avoiding obstacles.

Wireless communication modules such as Wi-Fi or LoRa will be used to transmit the collected data to a cloud-based IoT platform or a mobile/web application, enabling farmers to remotely monitor greenhouse conditions. The system can also include automation features like activating irrigation or ventilation systems based on environmental data. This approach minimizes manual labor, ensures optimal crop-growing conditions, and supports data-driven decision-making, ultimately improving productivity and resource efficiency in greenhouse farming

2-LITRATURE SURVEY

Agriculture forms the bedrock of societal welfare and international economic exchange [1]. With global food demand expected to surge by 70% by 2050 [2], the sector faces mounting pressure to enhance productivity. However, adverse climatic conditions such as droughts and floods have delayed crop seeding, limiting agricultural output to an estimated 3% increase [3]. Additionally, reliance on fertilizers and pesticides to mitigate environmental impacts and accelerate crop cycles often leads to soil degradation and diminished crop nutrition due to improper usage [4, 5]. In this landscape, greenhouses present a promising solution by enabling controlled cultivation environments, yet they come with their own operational challenges, such as maintaining uniform climate conditions [6, 7]. To address these complexities, technological interventions have emerged as transformative tools to ensure efficiency and sustainability in agriculture.

Emerging Technologies in Agriculture

The agriculture sector has embraced cutting-edge technologies, including the Internet of Things (IoT) and machine learning (ML), to overcome traditional farming limitations. IoT has revolutionized farming practices by interconnecting sensors, machinery, and human operators, laying the foundation for smart farming systems. These systems optimize resource utilization, reduce environmental impact, and enhance decision- making by integrating real-time data analysis. Moreover, ML applications are instrumental in uncovering patterns from large datasets, empowering farmers to address challenges proactively.

Challenges in Greenhouse Cultivation

Despite the promise of greenhouses, achieving uniform environmental conditions remains a persistent hurdle. Variations in humidity, irrigation, soil type, and geographical location can lead to unprofitable outcomes [7]. Furthermore, inexperienced farmers may inadvertently exacerbate these issues during crop management [8].

The Role of Autonomous Robots

Autonomous robots have emerged as key enablers in greenhouse operations, offering precise and efficient monitoring solutions. Equipped with advanced proportional- integral-derivative (PID) controllers, these robots can navigate harsh and uneven terrains while collecting vital data along planned crop routes. Unlike traditional wireless sensor networks (WSN), which are prone to energy inefficiencies and physical damage [4] autonomous robots provide resilient and adaptable solutions for modern greenhouses. Additionally, their ability to return to docking stations for battery recharging and sensor performance checks adds to their operational efficacy.

Machine Learning Applications for Smart Farming

Machine learning algorithms, particularly unsupervised ones like k-means clustering, play a pivotal role in identifying growth patterns. By classifying data into clusters representing optimal, standard, and deficient growth conditions, ML aids in targeted interventions. Importantly, these algorithms operate locally, overcoming bandwidth limitations typically faced in rural greenhouse setups. This localized approach ensures reliable and energy-efficient data processing.

Interactive Farmer-Robot Interfaces

To bridge the gap between technology and agricultural expertise, user-friendly graphical user interfaces (GUIs) have been developed. These GUIs enable farmers to plan robot routes, monitor environmental conditions, and make informed decisions based on data insights. The collaborative framework fosters a synergy between human intuition and machine intelligence, enhancing productivity and operational efficiency.

3-METHODOLOGY

Block diagram:

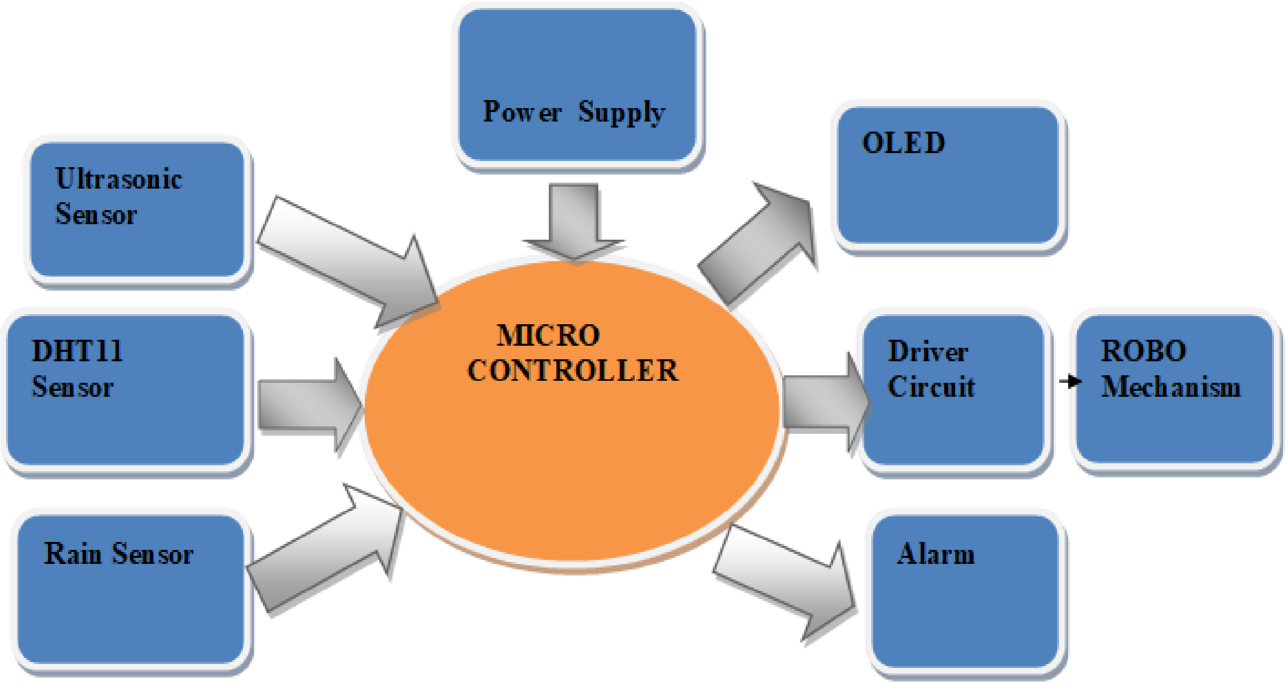

Fig.1 Project block diagram

Power supply

The power supply section is the section which provide +5V for the components to work. IC LM7805 is used for providing a constant power of +5V.

The ac voltage, typically 220V, is connected to a transformer, which steps down that ac voltage down to the level of the desired dc output. A diode rectifier then provides a full- wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation.

A regulator circuit removes the ripples and retains the same dc value even if the input dc voltage varies, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of the popular voltage regulator IC units.

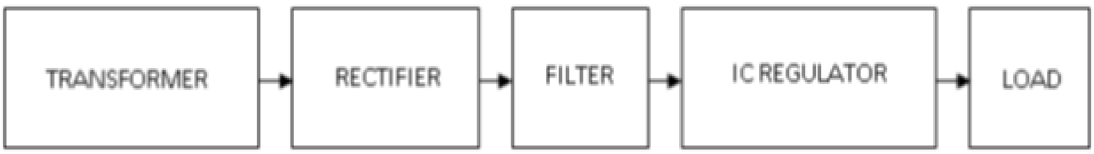

Fig.2 Block diagram of power supply

Transformer

Transformers convert AC electricity from one

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voltage to another with little loss of power. Transformers work only with AC, and this is one of the reasons why mains electricity is AC.

Step-up transformers increase voltage, step-down transformers reduce voltage. Most power supplies use a step-down transformer to reduce the dangerously high mains voltage (230V in India) to a safer low voltage.

The input coil is called the primary and the output coil is called the secondary. There is no electrical connection between the two coils; instead, they are linked by an alternating magnetic field created in the soft-iron core of the transformer. Transformers waste very little power so the power out is (almost) equal to the power in. Note that as voltage is stepped down current is stepped up.

The transformer will step down the power supply voltage (0-230V) to (0- 6V) level. Then the secondary of the potential transformer will be connected to the bridge rectifier, which is constructed with the help of PN junction diodes. The advantages of using bridge rectifier are it will give peak voltage output as DC.

Rectifier

There are several ways of connecting diodes to make a rectifier to convert AC to DC. The bridge rectifier is the most important and it produces full wave varying DC. A full-wave rectifier can also be made from just two diodes if a center-tap transformer is used, but this method is rarely used now that diodes are cheaper. A single diode can be used as a rectifier, but it only uses the positive (+) parts of the AC wave to produce half-wave varying DC.

4-WORKING PRINCIPLE & FLOW CHART

Environmental Sensing:

- The robot is equipped with sensors (temperature, humidity, soil moisture, light intensity, CO_2, rain, ultrasonic, etc.) to collect real-time data from the greenhouse environment.

Data Processing:

- A Raspberry Pi Pico microcontroller collects data from all sensors.
- The data is processed locally on the robot to minimize the need for internet/cloud access.

Autonomous Navigation:

- Using a PID controller and motor driver (L293D), the robot navigates autonomously along crop rows, even on uneven terrain.
- Obstacle avoidance is achieved using ultrasonic sensing.

Communication:

- Sensor data is transmitted wirelessly using LoRa or Wi-Fi to a central node for logging and further processing.

Machine Learning Application:

- An unsupervised ML algorithm (like K-means clustering) analyzes the collected environmental data to detect patterns of optimal, average, and poor crop growth conditions.

Farmer Interface:

- The data and ML results are displayed through a Graphical User Interface (GUI).
- Farmers can view suggestions, plan routes, and make informed decisions based on robot feedback.

Automation Control:

The robot or the system can autonomously activate actuators like irrigation or ventilation systems if environmental parameters cross thresholds.

Flow Chart

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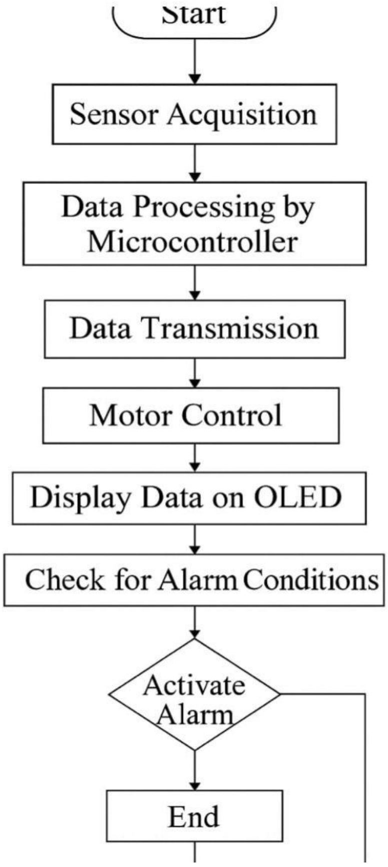

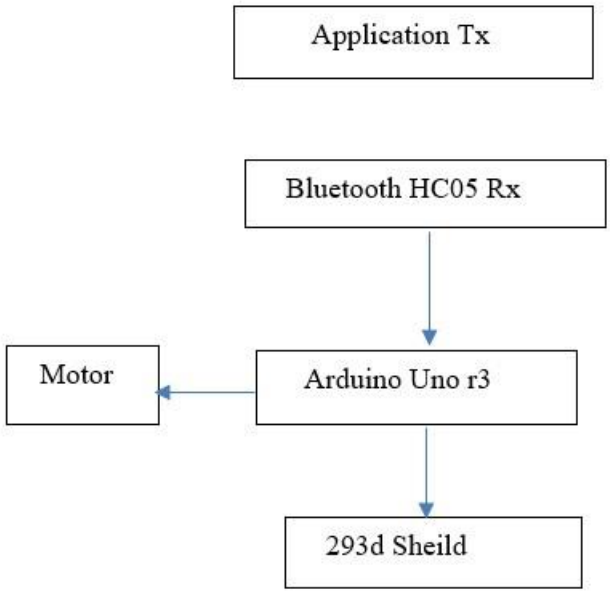

Fig 6.1 Flowchart

5-RESULT

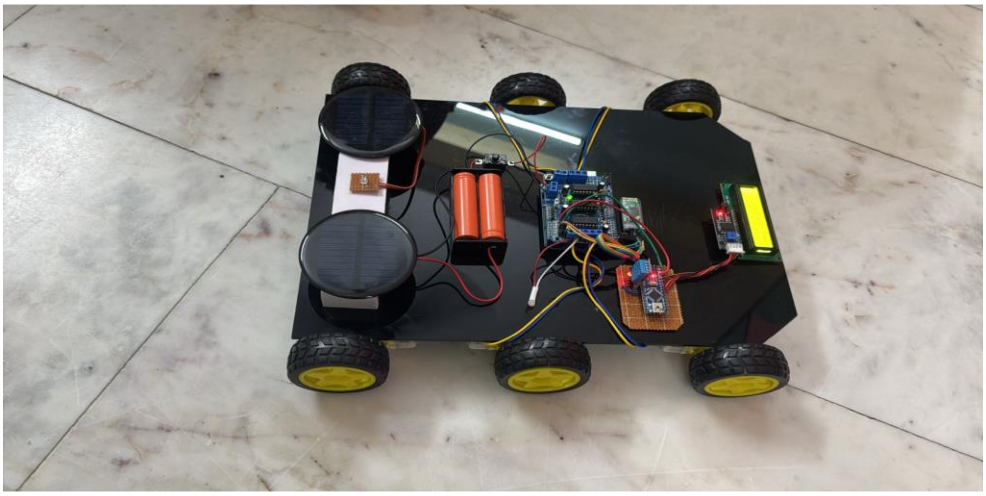

Fig 1: Hardware Kit When in ON condition

Fig 2: Temperature and Humidity Levels

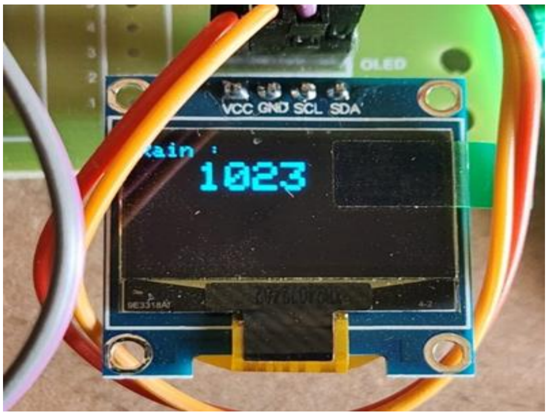

Fig 3: Display of Rain Detection

Fig .4: Ultrasonic sensors measuring the Distance

The successful development of the Smart Farming Robot for Detecting Environmental Conditions in a Greenhouse led to the following key achievements:

1. High-Resolution Environmental Monitoring:

• The system effectively detected greenhouse environmental factors using ultrasonic sensors, rain sensors, and DHT11 sensors to gather data on humidity, temperature, and other crucial conditions.

• Enabled real-time monitoring with high precision to ensure optimal crop growth.

2.Sensory Data Fusion:

• Integrated multiple sensors to comprehensively collect data on environmental parameters affecting plant health.

• Used sensory data fusion techniques to recommend corrective actions based on real-time readings.

3. Efficient Data Processing:

• The robot mechanism processed sensory inputs in real time to analyze greenhouse conditions and adapt its actions accordingly.

• Software integration ensured seamless data handling and system control for effective greenhouse monitoring.

4. Stable Connectivity:

• The system was equipped with communication modules to maintain reliable interaction with cloud platforms, ensuring dynamic updates and remote access.

5.Interactive Feedback Mechanism:

• The OLED display presented environmental readings and system status for immediate farmer feedback.

• The alarm system alerted users to critical environmental conditions, allowing timely intervention.

6. Adaptive Control Features:

• Implemented driver circuits to regulate robotic movements and enable responses to sensor inputs, ensuring optimal crop care.

• Recommended smart adjustments dynamically, improving overall greenhouse efficiency.

7. Scalability and Expansion Potential:

• The system design supports the integration of additional sensors and modules to expand functionality for diverse farming requirements.

8. Energy Efficiency:

• Operated with low power consumption, leveraging an optimized power management system for sustained operation.

9. Smart Decision Support:

• Generated insights based on environmental monitoring to assist farmers in making informed decisions about crop care and resource management.

6-CONCLUSION

The paper's findings emphasize that the wireless sensor network successfully gathered critical data from the greenhouse environment. By averaging ten samples, the occurrence of extreme observations was greatly reduced, enabling the machine learning model to provide an accurate representation of environmental conditions within the greenhouse. Additionally, the designed PID controller offers the capability to plan both straight and curvilinear trajectories, tailored to the crop's shape.

Its user-friendly interface enhances flexibility, allowing diverse products to be cultivated in the greenhouse. The study also revealed that, in the specific greenhouse tested, the data analysis identified zones where environmental conditions adversely impacted the crops, particularly near the door and water pump. These issues often arose due to the improper closure of the door, exposing crops to direct sunlight, and the malfunctioning water pump, which sometimes continued supplying water even after being turned off.

Looking ahead, the paper proposes the development of an autonomous robot equipped with computer vision to provide farmers with enhanced insights into their crops. This robot could also enable the activation of water pumps through smart systems that leverage efficient data processing techniques.

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