IoT based solar powered Agribot for Modern Agricultural Applications

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Abstract

India's agricultural sector plays a vital role in contributing to a significant portion of the country's GDP. However, it faces significant challenges such as water scarcity and escalating labor costs. To address these issues, the implementation of agriculture task automation is crucial, as it promotes precision agriculture. Taking into account India's abundant sunlight, this paper focuses on outlining the design and development of an IoT-based solar-powered Agribot. This innovative solution aims to automate irrigation tasks and facilitate remote farm monitoring, thereby offering potential resolutions to the aforementioned challenges. The Agribot, powered by an Arduino microcontroller, incorporates innovative features to optimize its functionality. It efficiently harnesses solar power during non-irrigation periods, ensuring sustainable operation. Additionally, the Agribot functions as an IoT device, utilizing a Wi-Fi link to transmit the collected sensor data to a remote server. At the remote server, the raw data undergoes a series of signal processing operations, including filtering, compression, and prediction. These operations refine and enhance the data, enabling more accurate analysis. The analyzed data statistics are then presented through an interactive interface, which can be accessed by users upon request. This interface provides valuable insights into the farm's irrigation status and allows users to make informed decisions based on the data presented.

Keywords: Agriculture, Agribot, IoT, Solar, Sensor and Controller.

1. Introduction

In the past, agricultural practices heavily relied on manual labor due to limited technological advancements. However, with the rapid development of technology, the scenario has changed significantly. Nowadays, robotics has revolutionized the farming industry, allowing individuals to oversee and control seeding processes comfortably from a cool and convenient location. Implementing robotic systems in agriculture has led to the exploration of new operational approaches and improved efficiency. Traditionally, agricultural tasks such as planting seeds, plowing, and weeding have been labor-intensive and greatly influenced by unpredictable weather conditions. Moreover, the equipment used for these operations has been bulky and cumbersome. Labor shortages caused by population migration to cities have exacerbated the challenges faced by the agricultural sector. However, the rise of robotics has brought about transformative changes not only in fields like medicine, industry, and entertainment but also in farming. By integrating existing technologies and robotics into agricultural systems, it is possible to enhance performance while reducing the overall time, effort, and costs involved. To achieve this, specialized robotic systems are employed on farms. These systems utilize motors to control various tasks such as harvesting, sowing, and watering crops. By automating these processes, farmers can streamline their operations and optimize resource allocation, leading to improved productivity and reduced manual labor requirements.

Our robot is powered by Intel's highly capable microcontroller, the 8051. Specifically, we utilize the AT89C2051 microcontroller IC2 as the primary controller. This microcontroller acts as the master controller, responsible for decoding commands received from the remote control unit or base station. It executes these commands and generates pulses for speed control. The LD293 motor ICs are employed to drive the two motors of the vehicle. These motors not only facilitate the movement of the robot but also power other agricultural attachments mounted on the vehicle. The microcontroller serves as the brain of the system, efficiently managing the commands received from various sources and coordinating the actions of the different components. Additionally, it processes data from sensors, ensuring that the system operates in a sensitive and responsive manner. To facilitate communication, a GSM module is incorporated into the system. This module enables users to select options and send instructions to the robot. Consequently, the robot can move in a specific direction as instructed by the user. Furthermore, our system emphasizes sustainability by utilizing solar energy. The robot is equipped with solar panels that harness sunlight to power the various components, including the GSM module. This ensures that the robot remains operational while minimizing its environmental impact.

The seed sowing process is accomplished using a DC motor in our project. The entire system's operations and information will be displayed on an LCD screen. The robot unit is powered by solar energy, utilizing sunlight as a sustainable power source. In the GSM application, users have the option to set the number of columns and steps for the robot's movement. The agricultural land is divided into columns and numbered steps to facilitate efficient navigation. To facilitate communication and data management, the project integrates with the Thingspeak cloud service[1]. When users input information, such as commands or settings, the system sends the message to the server for processing and storage. The system utilizes a booster to regulate the battery and solar voltage, ensuring a stable power supply for the robot unit. The advancement of electric-powered technological solutions has greatly influenced irrigation and agricultural task automation[2]. In India, the abundance of solar radiation is a significant advantage, with an average of 3000 hours of sunshine throughout the year, equating to approximately 4-7 kWh of solar radiation per square meter [3]. This makes solar-driven technological solutions highly beneficial for agricultural automation, considering the environmental conditions in India. Numerous technological solutions have been explored in the literature to achieve automation in agriculture tasks and enable remote monitoring of farmland. One such solution involves the development of a smart irrigation controller utilizing the PIC16F876A microcontroller [4]. This system employs an XBee link to transmit data to a remote server. However, the system is limited to monitoring moisture levels at a single point. To effectively monitor an entire farm area, a large number of sensors would need to be deployed, thereby increasing the overall cost of the system. Additionally, the XBee communication range is limited to 50 meters. Furthermore, the developed remote interface lacks signal processing capabilities to derive meaningful statistics relevant for farm monitoring. It is evident that while these existing solutions offer some level of automation and monitoring, they have certain limitations in terms of scalability, data processing, and communication range. Addressing these limitations is crucial for the successful implementation of comprehensive and efficient agricultural automation systems. A proposal for agricultural task automation involves a two-cell overhead crane system [5]. This system aims to automate tasks such as fertilizer spraying, irrigation, and seed planting through the use of a solar-driven crane. However, implementing such systems requires a substantial budget, and for effective farm monitoring, multiple sets of sensors must be strategically placed across different geographical points. This requirement adds to the overall cost of the system. Another proposed solution for agricultural automation is a wireless sensor network and GPRS-based technology [6]. This solution utilizes multiple sensors to monitor plant health and environmental parameters. Similarly, a smart GSM-controlled weather-based irrigation system has been developed [7], incorporating an ARM processor. This system senses soil moisture levels and irrigates the farm based on rain predictions. However, the implementation of both [6] and [7] necessitates a significant amount of hardware to form a sensor network across a geographically dispersed farm, further increasing costs. In addition to automated irrigation systems for farmland, automation can also benefit green roof irrigation, conserving water resources. A microcontroller-based irrigation system [8] has been developed, considering soil moisture, humidity, solar radiation, and wind speed. This system employs a single sensing node instead of multiple points. However, for a complete roof garden, multiple sensor nodes are still required. It is evident that while various automated solutions have been proposed, they often come with challenges related to cost, scalability, and the need for multiple sensor installations. Overcoming these challenges is crucial for the successful implementation of efficient and cost-effective agricultural automation systems. In contrast to the previously discussed systems, agricultural robots offer a promising solution for irrigation and agricultural task automation [9]. In this paper, we introduce the Agribot, a versatile robot capable of irrigating the farm, harnessing solar power during non-irrigation periods, and providing remote farm monitoring. The Agribot's design focuses on achieving better efficiency in water usage compared to manual irrigation methods. This is accomplished through direct soil moisture and humidity measurements at various locations within the farm. Unlike automated systems that rely on single-point data for irrigation decisions [10,11], the Agribot irrigates the farm based on averaged data obtained from multiple points. This eliminates the need for installing dedicated sensors at various positions throughout the farm. By moving around the farm, the Agribot collects data at different geographical points and transmits it to the cloud. This ensures historical data availability for the entire farm, allowing for future data prediction through appropriate analytics[12]. To improve data quality and storage, the collected data undergoes filtering to remove noise and compression for efficient storage.

2. Literature Survey

The primary objective of the seed-sowing operation is to plant the seeds at the proper depth and distance apart. This paper's main goal is to use solar energy to create the Agribot (Automatic Seed Sowing Machine). In the suggested system, the micro-controller receives the signal from ultrasonic sensors. After receiving the signal from the motor driver circuit and detecting the furrows in the agricultural field, Agribot automatically rotates and sows the seeds in the following line with the aid of a linear actuator. The battery that supplies the gear motors with the required power is charged by a solar panel.

A solar-powered autonomous pesticide spraying robot was suggested in [13] by the authors in an effort to utilise less energy and labour. The prototype was created by the author using an Arduino, an ultrasonic sensor, a motor driving circuit, a relay circuit to operate a sprayer circuit, and a battery supplied by a solar panel. The transmitter and receiver of the robot work at a high frequency of 434 MHz. It is an automated robot that the Arduino UNO R3 controls. Ultrasonic sensors and an Arduino UNO R3 are used to automate the robot. The process of mowing the grass is powered by DC motors. All of the system's components are powered by a DC battery.

Based on the new generation of information technology (IT), an integrated framework system platform embracing the Internet of Things (IoT) has been developed in China to improve the effectiveness and safety of production and administration of contemporary agriculture. Designed[14]. Machine learning methods play a significant part in the analysis of the information and data gathered from various datasets. Real-time analytics is used to forecast the state of the crops based on historical data. The system's security and ability to accurately extract data from massive data sets are its limitations. A sensor network was used in the study to collect field data on several crops (potatoes, tomatoes, etc.). The field data gathered from the deployed sensors (radiation, soil temperature, moisture, and air temperature).

This research [15] provides a thorough analysis of the IoT solutions that are currently available for use in agriculture. Some of the most important agricultural sectors that can be automated are soil monitoring, crop monitoring, IoT-based smart irrigation, and real-time weather forecasting.

Utilising IoT-based crop and soil monitoring, agricultural output may be increased while wasting is decreased via efficient water use. An IoT architecture for smart agriculture has been described, along with a schematic model of an IoT-based automated smart agricultural system that includes subsystems for real-time weather forecasting, crop monitoring, soil health monitoring, and IoT-based smart irrigation[16].

These techniques recognise the value of making the most of the available resources, including labour and water supply. Farmers are able to maximise their profit via this economising. The purpose of linear programming is to solve current issues in the actual world by assessing available resources and offering appropriate solutions[17]. This study examines a number of applications, such as crop rotation and pattern, irrigation water use, and product transformation, which are crucial to enhancing a number of agricultural industry facts. A discussion of the many methods that aid in optimising agricultural solutions will follow the overview.

Farmers must be careful to choose seeds with excellent heredity and maintain plantations in a manner that promotes the correct development of nursery plants while growing timber trees. Nutritional elements, sunshine, temperature, water, and soil moisture are a few things that help nursery plants develop. An Android-based monitoring system was developed to track the development of nursery plants with the goal of improving farmers' access to information and monitoring the supporting condition elements. A soil moisture sensor is one of several sensors in the system.

By using solar energy to power the agribot, the authors of [18] devised a system that minimises the labour cost and also shortens the time for digging operations and seed sowing operations. This machine uses a solar panel to collect solar energy, which is then transformed into electrical energy to charge a battery, which then supplies power to a shunt wound DC motor. To control the robot in the field, sensors are combined with a Wi-Fi interface run on an Android application[19]. This reduces reliance on manpower. A robot for seed sowing and excavating can travel across different types of terrain while performing digging, seed sowing, and ground closure.

The [20] authors created an agribot, a multipurpose robot that can carry out all farming tasks, such as tilling the soil of the field, planting seeds there, levelling the field with a leveller, watering the crops, fertilising them, and monitoring the agribot with a camera. There is a lot of physical effort required for traditional agricultural techniques. Both manually operated equipment and manual labour are used in some of the tasks. As a result, there are no robots that are capable of carrying out all of these tasks on their own. For a variety of reasons, the farmer must keep an eye on his or her land. The monitoring system makes this happen. Using a monitoring system, several aspects such as irrigation and temperature maintenance (for greenhouse farming) will be taken care.

3. DESIGN AND IMPLEMENTATION

The Agribot's automatic watering system is controlled by an Arduino-based ATmega2560 microcontroller. It is specifically designed to navigate the rectangular outline of the field. To determine the optimal amount of water required for irrigation, two critical factors are taken into account: soil moisture content and ambient temperature. Soil moisture is measured using the YL-69 sensor, while the LM-35 sensor measures ambient temperature. These sensors, along with a screw rod mechanism, gather data on the shape of the rectangular field. The collected data is processed by the Arduino microcontroller, which analyzes and interprets the information to ensure even watering of the soil near the sensing point. To transmit the gathered data to the cloud (ThingSpeak), an ESP8266 module is employed. The transmitted data includes information from both the temperature sensor and the soil moisture sensor. This data provides insights into the soil condition, enabling informed decisions on future irrigation practices. By leveraging these technologies, the Agribot's automatic watering system optimizes irrigation by considering the specific soil moisture and temperature requirements of the field. The integration of data processing and cloud connectivity enhances the efficiency and effectiveness of irrigation practices, leading to improved crop health and water management.

In this paper, the analysis mainly focuses on the filtering, prediction, and compression of the raw data collected. The system comprises three main components: the sensor, control unit, and output mechanism. The YL-69 soil moisture sensor, a resistance-based sensor, and the LM35 temperature sensor are used to measure soil humidity. The control unit is created using the ATMega2560 microcontroller, which is based on the Arduino platform. The output from the control unit is utilized to activate or deactivate the irrigation system based on the soil temperature and moisture levels.
The hardware components attached to the Agribot are essential for its operation. The Agribot's DC motor is powered by two H bridges, while a third H bridge controls the screw rod mechanism used for soil moisture measurement. The pump is controlled by a relay. Solar panels are used to convert solar energy into electrical energy for consumption. An LM7805 IC regulator is employed to convert the 12V DC supply into a 5V DC supply, which is used to drive the relay. The developed Agribot's block diagram illustrates the various sensors and components utilized. The YL-69 soil moisture sensor plays a crucial role in the Agribot system. It consists of two electrodes that measure the moisture content in the surrounding area. The resistance of the soil to the current passing through the electrodes provides information about the soil's moisture content. Higher moisture levels result in lower resistance, allowing more current to flow through the soil. The sensor is equipped with an LM393 comparator and a digital potentiometer on a compact PCB board, providing both digital and analog outputs. By utilizing these sensors and components, the Agribot system effectively measures and monitors soil moisture levels, enabling precise control of the irrigation system based on the specific requirements of the crops. This integration of sensors, control unit, and output mechanism enhances the efficiency and effectiveness of the Agribot's irrigation operations.

The LM35 temperature sensor is a precision device that provides an output voltage proportional to the temperature in degrees Celsius. It has three pins: Vcc, which is connected to the controller's supply, ground, which is connected to the controller's ground, and output, which is connected to one of the controller's analog pins. The LM35 sensor offers good accuracy, with an average accuracy of 1-2°C at room temperature and 3-4°C across the temperature range of -55°C to 150°C, without the need for external calibration. DC motors are used in the Agribot to facilitate the movement of the robot and assist the onboard sensors in reaching the soil while collecting data. A DC motor converts electrical energy from direct current (DC) into mechanical energy, enabling the Agribot to navigate and perform tasks. The L293D is a dual H-bridge motor driver IC used to control the DC motors. The motor driver acts as a current amplifier, converting a low-current control signal into a higher-current signal to drive the motors effectively. The L293D includes two integrated H-bridge driver circuits, allowing two DC motors to be operated simultaneously in both forward and backward directions. To control the watering operation, the Agribot employs a relay. Relay modules are electrical switches capable of handling higher voltages and currents than a microcontroller alone. They can be used to turn circuits on or off based on the control signals from the microcontroller. In the case of the Agribot, the relay is utilized to activate or deactivate the irrigation system, controlling the flow of water to the plants. These components, including the LM35 temperature sensor, DC motors, and relay, play vital roles in the functionality of the Agribot, enabling it to perform precise temperature measurements, navigate the farm, and control the irrigation system effectively.

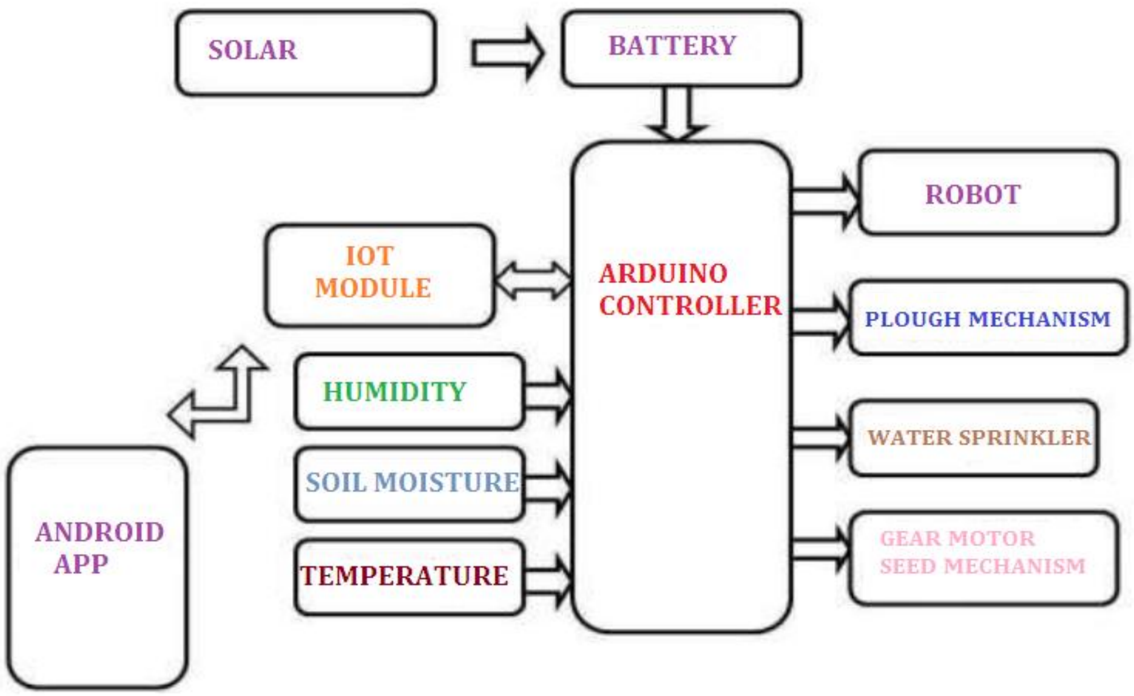

Figure.1: Block diagram of Agribot

4. Working of Agribot

The Agribot is programmed to go forward for a total of ten seconds.It will come to a stop at the first plant position. once inserting the soil moisture sensor into the ground with the assistance of the screw rod for a period of five seconds, the values from both sensors are stored in two separate arrays inside the micro controller. The soil moisture sensor is then relocated once the data have been saved. The WiFi module ESP8266 that is interfaced with the Arduino gathers an average of the data from the sensors and then transmits this information to the cloud. As a consequence of this, the Agribot functions as an Internet of Things device. When the Agribot travels to its next sensing point, the procedure that was just explained is carried out again. The agribot was designed to move in a straight line along the geometry of the rectangle, which contained two sensing points on each of its sides. After completing one circuit around the rectangular field, the findings from each sensor site are compared with a threshold value that is based on the time of year and the crop that is being cultivated. This allows the Agribot to predict how long it will take to water the plant after it has finished its rotation.Following the completion of the data calculation, the Agribot starts the second rotation of its journey along the presumed rectangular path. If the temperature is higher than 30, and the soil moisture measurement is between 750 and 1023, then water will be provided for five seconds. The soil moisture measurement must also be larger than 30. If the temperature is lower than thirty degrees and the moisture content of the soil is between seven hundred fifty and five hundred, then water will be provided for three seconds. In the event that the soil moisture value is lower than 450, the robot will move ahead for a period of 5 seconds before continuing the operation for the other sides. In the event that this occurs, water will not be given along one of the sides of the rectangle. To put it another way, if the values of the sensors drop below a given threshold.The motors have been pre-set to go forward while simultaneously watering the area close to the detecting point. In the event that the sensor value is higher than the threshold, the pump will simply pass over the region without watering it. The Agribot prototype is equipped with a total of five DC motors.The Agribot is driven by four, and one of them operates the mechanism that uses the screw rods. When taking measurements, the onboard sensors of the Agribot are able to go exceptionally near to the soil thanks to the screw rod mechanism, which also allows the sensors to return to their starting positions when they are not collecting data.

5. Results and Discussion

The image depicts the project's prototype. The set-up includes a sowing drum, plough rods for preparing the soil and a tank for watering the area. Many embedded systems share features and utilities with other systems. The structured vortex design is used in this project's construction, and the system's primary components are a single microcontroller CD, a GSM device, and a robot. For the project, a prototype module will be created. All of the block diagram's y interfaces are on a single PCB card. The rider will be attached to each PCB. The LCD screen is utilised to show all information outside the workplace for presentation inquiries. Information is sent to the robot unit via GSM, and it is powered by solar energy. The robot sings concisely forward, left, and right before dropping the seed. The base of the robot has four wheels that allow for flexible mobility. A microprocessor controls the water pump and uses relays to execute user commands. Every bit of data is kept in the database for further processing.

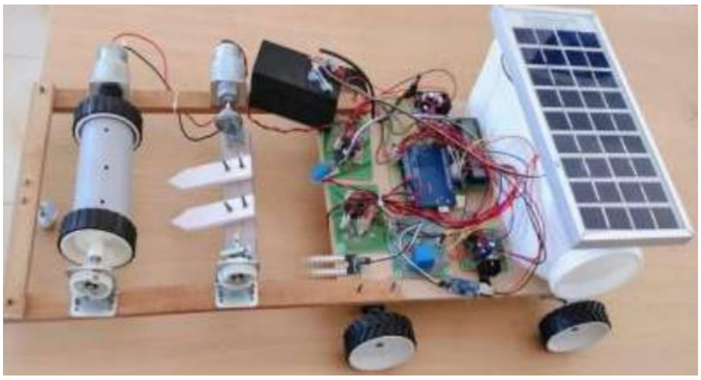

Figure.2: IoT based solar powered agribot kit

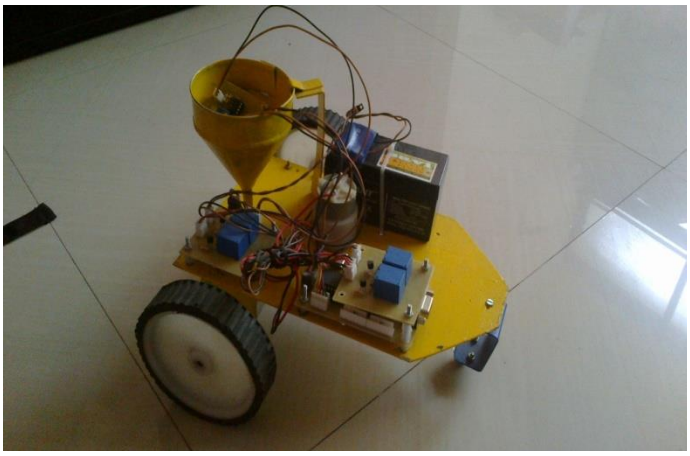

Figure.3: Agri-robot model for Agricultural applications

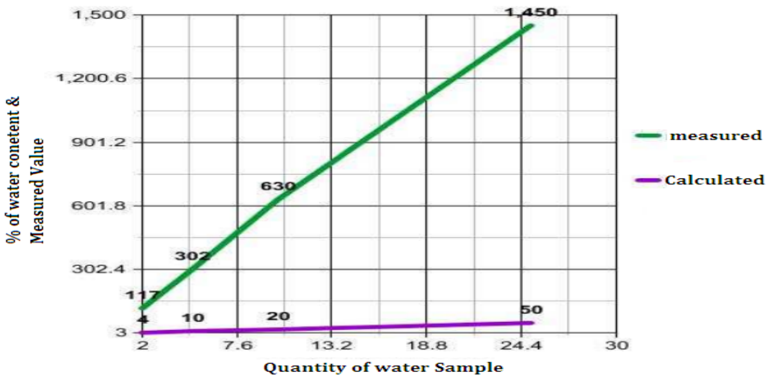

Figure.4: Graphical representation of analysis

The volumetric water content and temperature of the region are measured by a soil moisture sensor and a temperature sensor, respectively. In Fig. 4, the estimated and measured value are shown graphically. The cloud receives and continuously monitors the raw data. The raw data may be examined and compared at any time since it is permanently preserved in the cloud. It is possible to do data analysis, which aids in determining the locations where less water needs to be pumped and the locations where more water needs to be pushed until the value does not appear in the cloud. By preventing the needless pumping of water to a place where it is not required, much water is saved. Additionally, it protects the crop from too much water. By avoiding the locations where this clever procedure is allowed, time is saved and a great deal of support is provided.

6. Conclusion

This paper presents the development of an Agribot, designed to serve as an IoT device for remote farm monitoring, analysis, and irrigation. The Agribot operates solely on solar power and utilizes solar energy when irrigation is not required. Compared to fixed automation systems, the Agribot offers several advantages, including reduced hardware requirements. The developed Agribot is capable of irrigating the farm and transmitting data collected from different positions to the cloud. At the cloud end, the data is processed and analyzed to extract useful information and predictions. This analysis provides insights and recommendations for improving irrigation practices. Farmers have the flexibility to program the Agribot to perform specific tasks such as planting, harvesting, and applying pesticides. By leveraging IoT technology, the solar-powered Agribot enables farmers to effectively monitor the health of their crops. The Agribot's ability to operate autonomously, gather data from various positions, and transmit it to the cloud for analysis and prediction offers significant benefits for farmers. It streamlines farm monitoring processes, enhances decision-making, and allows for improved planning and optimization of irrigation practices. Overall, the IoT-based solar-powered Agribot serves as a valuable tool in modern agriculture, supporting farmers in effectively managing their crops and improving overall productivity. The Agribot's capabilities extend beyond irrigation and monitoring; it also plays a crucial role in detecting pests, diseases, and nutrient deficiencies in crops at an early stage. By identifying these issues promptly, farmers can take corrective measures to prevent irreversible damage to their crops. This early detection capability can significantly improve crop health and overall yield. Furthermore, the Agribot contributes to sustainable farming practices by reducing water usage and minimizing fertilizer waste. By precisely monitoring and controlling irrigation and nutrient application, it promotes efficient resource utilization, which is vital for environmental conservation and cost reduction. The Agribot's ability to optimize these factors leads to more sustainable agricultural operations and reduces the ecological impact of farming practices. In summary, the IoT-based solar-powered Agribot has the potential to revolutionize the agriculture industry. Its advanced capabilities in early pest and disease detection, optimized resource management, and sustainable farming practices make it a gamechanger for farmers worldwide. By leveraging this technology, farmers can enhance crop productivity, reduce environmental impact, and achieve more efficient and cost-effective farming operations.

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