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Application of IoT in Agriculture Monitoring

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ABSTRACT
India is predominantly an agricultural nation, with farming contributing a substantial share to the country's growth. Despite this, Farming faces persistent challenges such as inefficient water management, declining soil quality, and unpredictable climatic conditions, all of which adversely affect crop productivity and farmer profitability. In recent times, the adoption of smart agriculture technologies has gained importance to address these issues by optimizing crop yield and minimizing resource wastage. In this paper, we present an IoT-enabled smart system capable of monitoring temperature, humidity, and moisture levels, and transmitting this information to an IoT platform through the cloud. The system also supports both manual and wireless control via a mobile application using Bluetooth, allowing farmers to operate the robotic unit in real time. Unlike existing smart agriculture solutions that are often complex and costly, our proposed system is designed to be affordable, user-friendly, and efficient. By enabling farmers to manage resources effectively and take timely corrective actions when soil moisture drops below a set threshold, the system helps reduce crop losses.
Keywords – IoT, Robotics, Smart farming

I. INTRODUCTION

The agricultural sector is one of the most vital industries in India, providing livelihoods for a large portion of the population and contributing significantly to the national economy. However, it faces critical challenges such as water scarcity, inadequate irrigation infrastructure, and the absence of real-time monitoring and control systems. To overcome these limitations, there is a growing demand for innovative and cost-effective solutions that can help farmers optimize resource utilization and enhance crop productivity.

The urgency to increase agricultural output has intensified due to multiple factors, including the exponential growth of the global population, which, according to the United Nations Food and Agriculture Organization (FAO), will require 70% more food production by 2050. Compounding the issue are shrinking agricultural lands, declining soil fertility, depletion of freshwater resources, and yield stagnation in several staple crops. Additionally, changes in the agricultural workforce structure and a reduction in manual labor availability have further hindered productivity, pushing the adoption of advanced, technology-driven farming practices.

Traditional farming methods are no longer adequate to meet rising food demands, making modernization through technology essential. Precision agriculture has emerged as a promising approach that leverages advanced tools to maximize yield while minimizing resource wastage. Among these, IoT-powered smart agriculture systems hold great potential by delivering real-time insights into crop and environmental conditions, enabling farmers to make informed decisions regarding irrigation, fertilization, and pest management [5][6].

One of the most pressing challenges farmers face is the lack of access to accurate and timely information about crop health and soil conditions. IoT-based systems address this by continuously monitoring parameters such as temperature, humidity, and soil moisture content. This data enables farmers to make data-driven decisions on irrigation schedules and fertilizer application, reducing inefficiencies. Furthermore, the overuse of water, fertilizers, and pesticides not only increases production costs but also causes severe environmental damage. IoT solutions can help optimize input usage according to real-time crop needs and environmental conditions. Another critical issue is pest and disease outbreaks, which are traditionally managed using chemical pesticides that harm both ecosystems and human health [5]. IoT systems can aid in early detection of such threats by monitoring plant health indicators and environmental parameters, thus preventing large-scale losses.

The proposed system aims to provide farmers with a sustainable and cost-effective precision agriculture solution by integrating IoT technologies. Through continuous real-time monitoring of crop and environmental parameters, the system enables resource optimization, reduces wastage, and minimizes crop losses caused by pests and diseases. Ultimately, this approach enhances crop yield and profitability while promoting sustainable agricultural practices and reducing environmental harm.

II. PROPOSED SYSTEM

2.1 Block Diagram

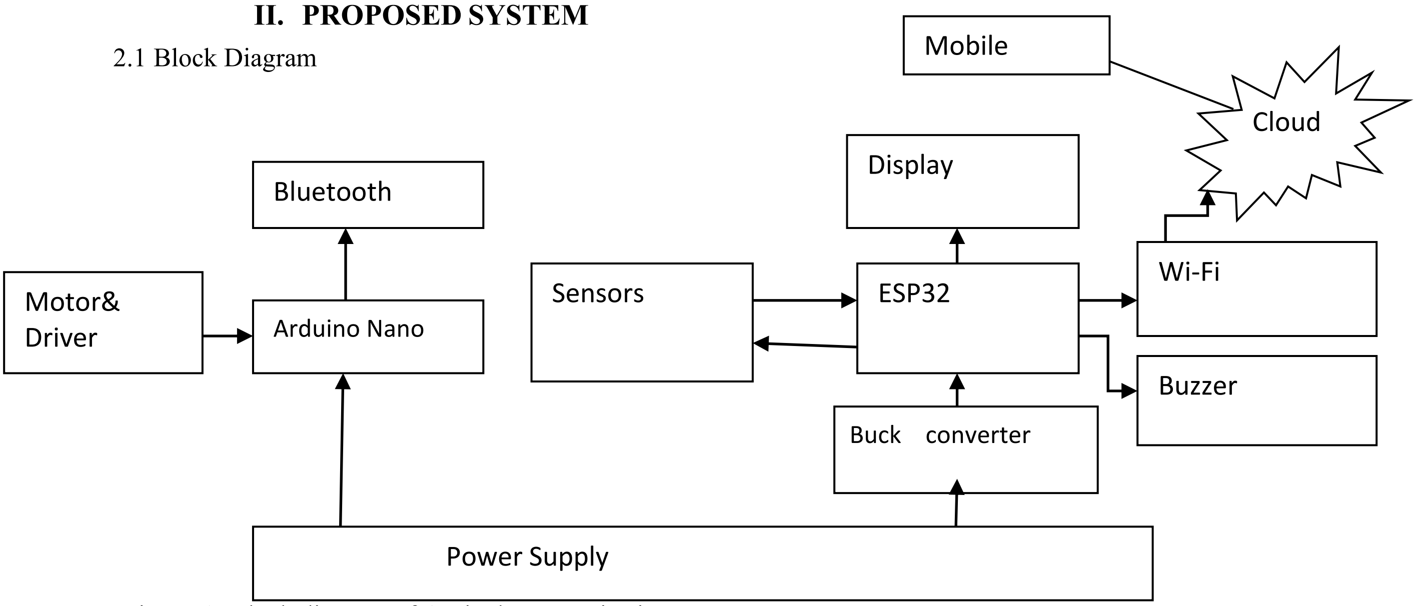

Figure-1: Block diagram of Agriculture monitoring System

The block diagram of the proposed system is illustrated in Figure-1. which depicts the interconnection and functional relationship between the different components. The hardware modules are integrated according to this design to ensure smooth operation. The system employs two microcontrollers: Arduino and ESP32. The Arduino functions as the control unit, managing the robotic car's movements, while the ESP32 serves as the sensing and communication unit, responsible for collecting accurate data from sensors before transmitting it to the cloud for further analysis. The ESP32's inbuilt Wi-Fi capability enables real-time data transmission to the IoT platform ThingSpeak, where the historical records of the sensed data are stored and analyzed. Additionally, a customized mobile application is developed to remotely control the robotic car's movements and simultaneously access sensor readings, including temperature, humidity, and soil moisture [8].

2.1 Hardware Specification

- ESP 32

The ESP32 microcontroller is a versatile and powerful module widely used for IoT applications, particularly due to its integrated Wi-Fi capabilities and robust processing power. In this work, we propose a system that employs the ESP32 to sense Temperature, humidity, and soil moisture levels using connected sensors, and transmit this data to the cloud in real time via the internet. The ESP32 is well-suited for this application, featuring a dual-core processor operating at up to 240 MHz, 520 KB of SRAM, and up to 16 MB of flash memory. It also supports Wi-Fi 802.11 b/g/n standards, ensuring compatibility with a wide range of networks. To acquire environmental data, a DHT11 sensor and a soil moisture sensor module are interfaced with the ESP32, providing accurate and continuous measurements of field conditions. Leveraging its built-in Wi-Fi, the ESP32 transmits the sensed data to cloud-based IoT platforms such as ThingSpeak IoT Cloud, where it can be stored, accessed, and analyzed in real time. By combining efficient sensing, real-time communication, and cloud integration, the ESP32 enables effective monitoring and analysis of environmental parameters, thereby supporting smart agriculture applications.

❖ **Arduino Nano**

The Arduino Nano is a compact and cost-effective microcontroller board widely used in robotics and embedded systems. In the proposed system, it is utilized to control the motors of a robotic car, enabling wireless real-time operation. The Arduino Nano is programmed to receive commands wirelessly via a Bluetooth module, which communicates with a smart phone application. These commands are then processed and translated into motor actions, controlling the speed and direction of the wheels through a motor driver. This setup provides efficient and precise wireless control of the robotic car's movement, making it highly suitable for applications that require remote operation. Furthermore, the Arduino Nano's small form factor, affordability, and ease of programming make it an attractive choice for robotics-based projects.

❖ DC Motor & Motor Driver:

DC motors are widely used in robotics and automation applications where precise control of motion is required. In the proposed system, DC motors are employed to drive the wheels of the robotic car, with their operation managed by an L298N motor driver module. The motor driver acts as an interface between the motors and the Arduino Nano, supplying the required power and control signals to regulate speed and direction. The Arduino Nano, in turn, receives wireless commands via a Bluetooth module connected to a smart phone application. These commands are processed and transmitted through the motor driver to control the DC motors, enabling real-time wireless navigation of the robotic car.

❖ Temperature Sensor

The DHT11 is a low-cost digital temperature and humidity sensor module widely used in applications such as home automation, weather monitoring, and smart agriculture. Compact in size and easy to interface, it is an ideal choice for projects where space and cost efficiency are important. The sensor incorporates a built-in thermistor for temperature measurement and a capacitive humidity sensor for humidity detection, providing accurate and reliable readings. It's simple communication protocol ensures seamless integration with a wide range of microcontrollers, making it a practical and efficient solution for real-time environmental monitoring.

❖ Lithium-Ion Rechargeable Batteries:

In the proposed system, four rechargeable lithium-ion batteries are used to supply power to the two 10 RPM motors as well as the entire electronic circuit. Lithium-ion batteries are a popular choice for portable devices due to their high energy density, lightweight design, and long cycle life. With a rated voltage of 3.7V per cell, these batteries provide sufficient power to operate both the motors and other electronic components, ensuring reliable performance. Their rechargeable nature allows them to be conveniently recharged using a suitable charging circuit, eliminating the need for frequent replacements. By integrating lithium-ion batteries, the system achieves a reliable, efficient, and sustainable power source, enabling extended operation of the robotic car without frequent interruptions.

❖ Soil Moisture Sensor:

The soil moisture sensor is a device designed to measure the water content present in the soil, making it highly useful in agriculture and gardening applications to ensure that plants receive the appropriate amount of water. The sensor consists of two probes that are inserted into the soil, and it operates by measuring the electrical resistance between them. When the soil has higher moisture content, the resistance decreases, whereas drier soil results in higher resistance. This simple yet effective mechanism allows the sensor to provide accurate readings of soil moisture levels. By using this sensor, farmers and gardeners can avoid problems caused by over-watering or under-watering, which can negatively impact plant growth and yield. Its ease of use, low cost, and reliability make it an essential tool for precision agriculture and smart irrigation systems.

❖ Buck Converter:

In the proposed system, a Buck converter is employed to provide a stable DC supply to the ESP32 microcontroller. A Buck converter is a type of DC–DC converter that steps down a higher input voltage to a lower, stable output voltage while maintaining efficient power transfer. Since the ESP32 requires a consistent DC supply for proper operation, the Buck converter serves as an ideal choice for this application. It delivers a regulated output voltage independent of fluctuations in the input, ensuring system stability. Moreover, Buck converters are known for their high efficiency, converting input power to the desired output with minimal energy loss. This makes them especially suitable for battery-powered systems, where power efficiency is critical. Overall, integrating a Buck converter guarantees a reliable, efficient, and stable power source for the ESP32, making it an essential component in the system design.

❖ Bluetooth HC-05:

The Bluetooth HC-05 is a compact and low-cost module that enables wireless communication between the robotic car and a mobile application. Widely used in applications such as home automation, wireless control systems, and robotics, it provides a reliable solution for short-range communication. In the proposed system, the HC-05 module is integrated with the microcontroller to allow the robotic car to be controlled via a smart phone application. The mobile app sends control signals to the HC-05 module, which then transmits the data to the microcontroller. Based on these signals, the microcontroller directs the robotic car’s movements. This setup allows users to operate the robotic car remotely, offering a convenient, efficient, and user-friendly control mechanism [2][6].

❖ Buzzer

The buzzer is a simple audio device used to provide an audible alert in response to signals from the soil moisture sensor module. In the proposed system, the buzzer is activated when the soil moisture sensor detects that the soil is too dry. Upon receiving this signal, the microcontroller triggers the buzzer, which produces a sound audible to the user, indicating that the soil needs watering. This solution is both simple and effective, allowing the user to monitor soil moisture levels without constantly checking sensor readings. By providing a clear and immediate alert, the buzzer ensures that plants receive the required amount of water to support healthy growth and development.

❖ OLED Display

The OLED display is a compact, low-power module used to visually present data such as the temperature and humidity readings measured by the DHT11 sensor. In this system, the OLED display provides real-time environmental data to the user in a clear and easy-to-read format. Capable of displaying both text and simple graphics, it enhances the user’s ability to monitor conditions effectively. Its low power consumption makes it particularly suitable for battery-powered applications, as it does not significantly impact the overall energy usage of the system. This combination of readability, efficiency, and reliability makes the OLED display an ideal choice for smart agriculture applications where real-time monitoring and power efficiency are critical.

2.3 Software

❖ Arduino IDE

The Arduino IDE software platform is used to program the Arduino Nano and ESP32 microcontrollers in the proposed system. It provides a user-friendly graphical interface and a simplified programming language based on C/C++, making it easier for developers to write and upload code to microcontroller boards. The IDE includes a built-in code editor with features such as syntax highlighting, auto-completion, and error detection, which simplify the process of writing, testing, and debugging code. Additionally, it offers a serial monitor that enables real-time debugging and data visualization. With a wide range of built-in libraries and example codes, developers can easily integrate functionalities such as sensor interfacing, motor control, and device communication into their projects. To program the Arduino Nano or ESP32, the user simply selects the appropriate board and port settings, writes the code in the editor, and uploads it to the microcontroller via a USB cable. Due to its versatility, ease of use, and extensive community support, the Arduino IDE is a widely adopted platform suitable for both beginners and experienced developers in diverse embedded system projects.

III. SCHEMATIC DIAGRAM

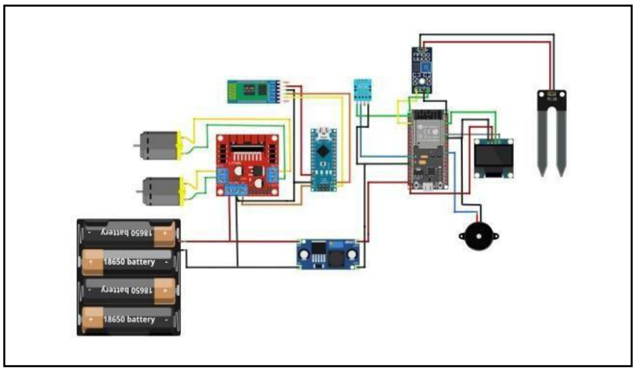

Figure-2 .Circuit Diagram Agriculture Monitoring System

IV. FUNCTIONING

When the system is powered ON using rechargeable Lithium-ion batteries, it activates the Arduino Nano and ESP32 microcontrollers, which initialize the control and sensing units of the proposed system. Once powered, the user can connect to the system through a dedicated mobile application via Bluetooth. To establish the connection, the user simply needs to enable Bluetooth on their mobile device, identify the system under available devices, and pair it using the correct password. After a successful connection, the authorized user gains access to the complete Smart IoT system.

Through the mobile application, the user can monitor real-time data of key agricultural parameters such as temperature, humidity, and soil moisture content. The system is designed so that if the soil moisture level detected by the sensor falls below a predefined threshold, a buzzer is triggered and a notification is displayed on the application. In addition, the user can wirelessly control the movement of the robotic car on which the system is mounted, making the system multifunctional and user-friendly.

The mobile application not only allows smooth control of robotic movements but also displays real-time agricultural data in an easy-to-read format. Furthermore, all collected data is stored on the ThingSpeak IoT cloud platform, enabling farmers to access both current and historical records. This information can be analyzed to determine optimal conditions for improving agricultural yield across different portions of farmland.

V. ALGORITHMS

Algorithm to Read Sensor Data

1. Start
2. Read from the Sensor
3. Display the data
4. Establish Connection with cloud
5. Transfer data to cloud
6. Read data from cloud to mobile application
7. Is moisture content is low

   If yes, turn Buzzer on else turn Buzzer off
8. Repeat the process
9 . End

Algorithm for controlling unit

1. Start
2. Open the application
3. Connect to the system via Bluetooth

4. Move the system in required direction such as LEFT/RIGHT/FORWARD/BACKWARD

5. Read the data from farming land and transfer to cloud

6. Repeat the process.

7. End

VI. RESULT AND DISCUSSION

The system sends the data collected by the sensors to the IoT-based platform ThingSpeak, where both historical and current data are stored. This data is represented in the form of graphs for each parameter, as shown in the figure, and is further used for data-based analysis. The latest readings displayed on ThingSpeak are fetched in real time using the ThingSpeak API, and these values are displayed on the mobile application, as illustrated. Overall, the system helps farmers or users determine whether the current conditions in the agricultural field are suitable for different crops without being physically present all the time. This reduces labor effort while providing constant and accurate results.

VII. CONCLUSION

In summary, the proposed system offers an innovative solution to the challenges faced by the agricultural sector in India. By providing farmers with real-time data and control over their crops, it has the potential to increase yields, reduce resource wastage, and promote environmental sustainability. Its simplicity, affordability, and accessibility make it especially valuable for farmers in rural areas, where access to advanced agricultural technologies is often limited. Overall, this system represents a significant step toward the development of smart and sustainable agricultural practices in India, with the potential to greatly improve farmers' livelihoods and strengthen the overall health of the agricultural sector.

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