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IOT BASED MULTI PURPOSE AGRICULTURE ROBOT

S. V Abinesh, Dr. P. Preethi, R.Levin, R.Vishal,

[1]**B. Tech IT,** Kongunadu College of Engineering and Technology, Trichy.
svabinesh9@gmail.com

[2]**Associate Professor,** Department of Information Technology Kongunadu College of Engineering and Technology, Trichy. preethi1.infotech@gmail.com

[3]**B. Tech IT,** Kongunadu College of Engineering and Technology, Trichy.
levinxben@gmail.com

[4]**B. Tech IT,** Kongunadu College of Engineering and Technology, Trichy.
vishal13codes.dev@gmail.com

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Abstract— Increasing demand of sustainable and efficient agriculture has brought into light the necessity of intelligent automation systems to minimize manual work, maximize the use of resources, and enhance the crop productivity. The present paper describes the design and construction of an IoT connected multipurpose agriculture robot, which is a unified robotic platform that incorporates real-time soil monitoring, automated irrigation, and remote communication with farmers. The system uses soil moisture sensors and a micro controller- based control unit to measure the conditions of fields and activate irrigation under specific predetermined thresholds. The IoT communication through the cloud-based interface provides real-time alerts and allows controlling the irrigation activities with the help of a user. The proposed system will improve the efficiency of water use, decrease the human factor, and promote smart and sustainable farming with the help of automation, IoT connectivity, and the user-in-the-loop decision making.

Keywords: IoT, Smart Agriculture, Agriculture Robot, Automated Irrigation, Soil Moisture Sensor

I. INTRODUCTION

The growing expectations of sustainable food production and effective agricultural practices have pointed out the constraints of the conventional way of farming as it greatly depends on manual labor and ineffective use of resources. Problems like excessive water consumption, neglect of crops, and absence of constant observation of the fields have a great impact on crop production and efficiency. The lack of real time information and automated control systems usually makes farmers suffer in terms of the inability to make timely decisions that would lead to the growth of labor dependency and resource wastage. Nevertheless, most of the current solutions are narrow in their applications since they only cover a single functionality like irrigation or.monitoring, and lack an integrated, multipurpose robotic framework capable of performing coordinated agricultural tasks [1]. To address these challenges, this paper proposes an IoT-Based Multipurpose Agriculture Combination of autonomous navigation, real-time sensing, automated irrigation, and remote monitoring into a single system. The suggested system will use a microcontroller-based intelligent control unit, which will analyze sensor data and analyze the conditions of the soil according to the set threshold values. Once the moisture content of the soil is low relative to the optimum

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level, the system blows on relay-operated irrigation systems to maintain a high degree of accuracy and efficiency in the delivery of water, hence reducing the wastage of resources and enhancing the health of crops [2]. The system is also augmented with the IoT cloud connection that allows sending data in real-time and monitoring it remotely with the use of mobile and web applications. The instant alerts and manual override option will enable farmers to communicate with the system as she moves around to make sure that user-in-the-loop decisions are taken as and when necessary. These cloud-based control systems enhance accessibility, responsiveness as well as operational reliability in farm settings [3]. The proposed system will enable precision farming and scalable deployment in a wide variety of agricultural environments by combining sensing, actuation, communication and control in a single robotic platform [4]. The general layout is more automation, efficiency and sustainability, which is flexible to farming conditions in the real world and the small- to medium-scale farms [5].

II. RELATED WORKS

Several researchers have contributed to the research of IoT, based smart farming and multifunctional agricultural robots. Patel and Desai suggested an IoT smart farming system with sensor networks and cloud, based irrigation control that can lead to a significant improvement in resource efficiency [1]. Soorya and Jidhu George came up with a modular IoT, enabled robot that can perform seeding, spraying, and soil monitoring [2]. Kundu et al. from the perspective of mechanical design, created a device flexible cultivator for ploughing, sowing, and leveling to help small farmers [3]. Soni and Khan have also talked about the autonomous mobility of the field robot they used grid, based navigation and obstacle avoidance techniques to complete the field coverage in an efficient manner [4]. Sharma and Kumar exemplified sensor, driven irrigation and fertilization supported by cloud analytics as part of precision farming methods [5].Multipurpose agricultural robots are embedded with sensors, actuators, and cloud dashboards that enable the farmer to perform IoT, based real, time monitoring and scalable automation; great emphasis is given to these in the work of Benazir Begam et al. [6]. Reddy and Naidu pointed out the affordability factor in their low, cost IoT agricultural robot for rural areas [7]. An autonomous farming robot was constructed by Verma et al., which is much more focused on autonomous control and automation on board than IoT connectivity [8].

Patil and Kulkarni demonstrated mobile, based remote control through a multitasking IoT robot performing seeding, spraying, and monitoring tasks [9]. Chavan et al. also pointed out sensor, based autonomous operation as a way of drastically limiting human intervention [10]. Mahajan and Patankar, in their robotic multipurpose system for agriculture, showed that mechanical, electronic integration can result in labor saving and increase in output [11]. [12] extends IoT, cloud security, [13] makes wireless sensor performance more efficient, [14] facilitates smart accessibility through detection systems, and [15] elevates data, driven service optimization. These, in combination, are the backbone of secure, efficient, and intelligent IoT environments that are pertinent to automated monitoring and control applications [16].

III. PROPOSED APPROACH

The suggested IoT-Based Multipurpose Agriculture Robot is based on the real-time sensing, automated control, and cloud-based communication to overcome major issues of modern agriculture which include inefficient irrigation, overworking of the workers, and absence of field monitoring on a regular basis. This system is established with a single autonomous robotic system with soil moisture and environmental sensors that constantly gather field data and send it to a centralized IoT cloud interface. The sensed data is processed [17-20].

A. Sensor & Data Acquisition Module

The Sensor and Data Acquisition Module is responsible for continuously monitoring real-time field parameters essential for effective irrigation and crop management. This module employs soil moisture sensors to measure the water content present in the soil and environmental sensors to monitor temperature and humidity conditions. The sensed data is collected at regular intervals and transmitted to the microcontroller [21] in raw analog or digital form Accurate and reliable data acquisition enables

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timely irrigation decisions and forms the foundation for automated control within the system.

B. **IoT Cloud Communication Module (Blynk)**

The IoT Cloud Communication Module enables seamless data exchange between the agriculture robot and the remote user interface through the Blynk IoT platform. Sensor readings and system status information are uploaded to the cloud in real time using Wi- Fi connectivity. This module ensures continuous synchronization between the field unit and the mobile or web application, allowing farmers to remotely monitor field conditions from any location. Additionally, control commands such as pump activation [22] and mode selection are received from the cloud and forwarded to the controller, enabling real-time remote operation and manual override functionality.

Figure 1. IoT Cloud Communication Module (Blynk)

C. User Interface & Alert Module

Figure 2. User Interface & Alert Module

The User Interface and Alert Module provides a centralized dashboard for visualizing real-time sensor data and system status. Through the Blynk mobile application, users can observe soil moisture levels, irrigation activity, and operational alerts in an intuitive format. The module generates instant notifications when critical conditions such as low soil moisture are detected, ensuring timely user awareness. Manual control options are also provided, allowing farmers to override automated decisions when necessary.

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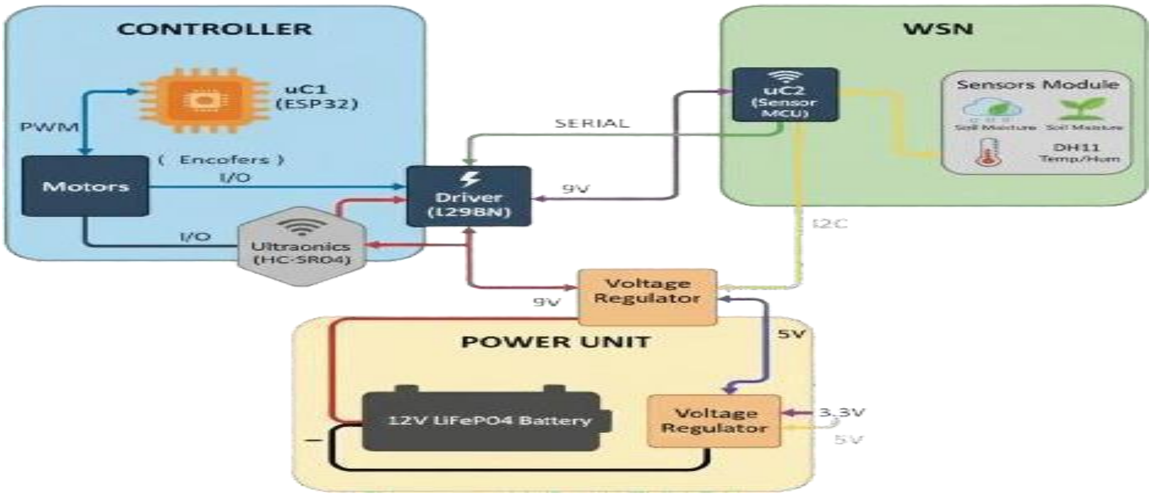

Figure 3. Architecture of the IOT-Based Multipurpose Agriculture Robot

Figure 3 illustrates the overall architecture of the IoT-Based Multipurpose Agriculture Robot and highlights the end-to- end flow of sensing, data processing, decision-making, and actuation. The system consists of field- deployed sensors, a microcontroller-based control unit, IoT cloud communication, and actuation modules for automated irrigation and rover movement. Sensor data such as soil moisture and environmental parameters are continuously collected through the Sensor and Data Acquisition Module and transmitted to the controller for real-time processing.
The microcontroller evaluates the incoming sensor data using predefined threshold-based logic to determine irrigation requirements and operational actions. Communication with the cloud is established through the IoT Cloud Communication Module (Blynk), enabling secure and reliable data synchronization between the field unit and the mobile or web application. Farmers can access real-time field information, receive alerts, and issue control commands through the User Interface Module. Based on the control decisions, the Relay and Pump Control Module activates or deactivates the irrigation pump to ensure precise water delivery. Simultaneously, the Motor Driver module controls rover movement for field traversal when required. The Power Management Module supplies regulated power to all system components, ensuring stable and uninterrupted operation. This integrated architecture supports efficient automation, real- time monitoring, and user-in-the-loop control, thereby enhancing precision farming and sustainable agricultural practices.

D. **Relay & Pump Control Module**

The Relay and Pump Control Module acts as the interface between the low-power controller and the high- power irrigation pump. Based on decisions made by the control algorithm, the controller activates the relay to switch the water pump ON or OFF. This module ensures safe electrical isolation and reliable operation of the irrigation mechanism. By enabling precise control of water delivery, the relay-based switching system prevents over-irrigation and optimizes water usage, thereby supporting efficient and sustainable farming operations.

E. ALGORITHM STRUCTURE

1. **Threshold-Based Irrigation Decision Algorithm:**

Soil moisture values are continuously compared with predefined threshold levels. When the moisture falls below the threshold, the irrigation pump is activated; otherwise, the system remains in monitoring mode. This ensures efficient water usage and prevents over-irrigation.

2. **Rule-Based Control Algorithm**:

The system operates using predefined rules to control irrigation and rover movement based on sensor inputs and user commands. This deterministic approach ensures reliable and predictable real-time operation.

3. **Event-Driven Alert Algorithm:**

Alerts are generated only when significant events such as low soil moisture or pump status changes occur. Notifications are sent through the IoT platform to inform the farmer promptly while avoiding unnecessary alerts.

4. **Manual Override Control Algorithm:**

When manual mode is enabled, user commands from the mobile application take priority over automatic decisions. This allows remote control of irrigation and rover movement when required.

IV. EXPERIMENTAL RESULTS

The experimental evaluation of the proposed IoT- Based Multipurpose Agriculture Robot confirms that the system performs reliably under real-time field conditions. During testing, the soil moisture sensor accurately detected variations in soil moisture levels, and the controller responded correctly based on predefined threshold values. When the soil moisture level dropped below the threshold, the irrigation pump was automatically activated, and when sufficient moisture was detected, the pump was turned OFF, preventing over-irrigation.The IoT cloud communication using the Blynk platform functioned consistently, enabling real-time transmission of sensor data to the mobile application. Farmers were able to monitor soil conditions remotely and control the irrigation pump manually through the mobile interface whenever required. Event-driven alerts were successfully generated and delivered to the user when critical conditions such as low soil moisture were detected, ensuring timely awareness and quick response.The relay and pump control module operated safely and reliably, with no false triggering observed during normal moisture conditions. The power management module provided stable operation throughout the experiment, ensuring uninterrupted functionality of sensors, controller, and communication modules. Overall, the experimental results demonstrate improved water efficiency, reduced manual intervention, accurate decision-making, and effective remote monitoring, validating the suitability of the proposed system for smart and sustainable agricultural applications.

A. *Dataset/ Test Conditions*

The proposed system was evaluated under different soil moisture conditions to validate its performance in real- world agricultural scenarios. Multiple test cases were conducted by varying soil moisture levels manually and observing system behavior. The experiments included dry soil conditions, optimal moisture levels, and over-moist soil conditions to assess the reliability of sensor readings and control decisions.

Test Conditions	Data Type	Analysis Task
Dry Soil	Soil Moisture Values	Irrigati on Activat ion
Optimal Soil Moisture	Sensor Readings	Monitoring Mode
High Moisture	Sensor Readings	Irrigation Suppression

Table1: Datasets Used

B.

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C. ***Output :***

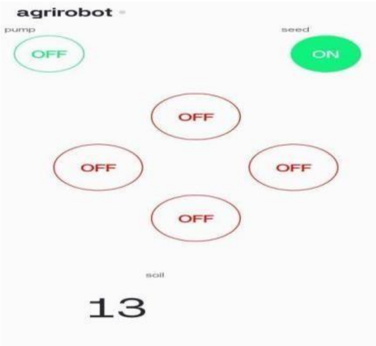

Figure 4 : Blynk IoT Output Interface for System Control

Figure 4 illustrates the Blynk IoT mobile application interface used for real-time monitoring and control of the proposed IoT- Based Multipurpose AgricultureRobot. The interface displays live sensor data such as soil moisture values and system status, enabling and continuous observation of field conditions. It also provides control options to manually activate or deactivate the irrigation pump and control rover operations when required. Instant alerts are generated through the application when soil moisture levels fall below the predefined threshold, ensuring timely user awareness and intervention. The Blynk-based interface confirms reliable cloud communication, user-in- the-loop control, and effective IoT integration for smart agricultural applications.

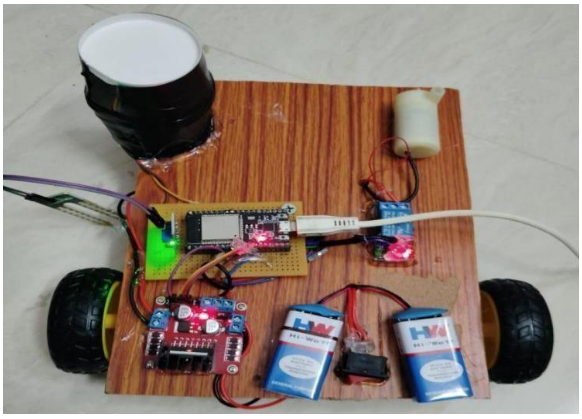

Figure 5 :Final Hardware Implementation of IoT-Based Multipurpose Agriculture Robote

Figure 5 shows the final working prototype of the proposed IoT-Based Multipurpose Agriculture Robot. The hardware setup consists of an ESP32 microcontroller mounted on a base platform, interfaced with a soil moisture sensor, relay module, water pump, motor driver, DC motors, and power supply units Based on the sensor readings and predefined threshold values, the ESP32 controls the relay module to activate or deactivate the water pump for automated irrigation.

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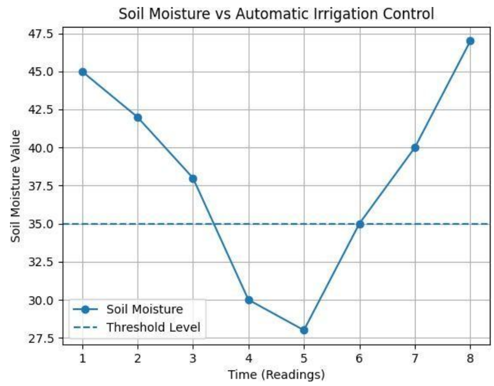

Figure 6:Soil Moisture vs Irrigation Status

Figure 6 shows the variation of soil moisture over time with respect to a predefined threshold. When the moisture level falls below the threshold, the irrigation pump is automatically activated, and it is turned OFF when the moisture level is sufficient. This confirms the effectiveness of the threshold- based irrigation control and efficient water usage.

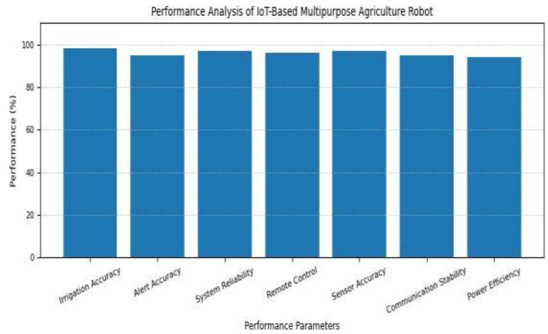

Figure 7:Irrigation Decision Accuracy **Figure 7** illustrates the performance analysis of the proposed IoT-based multipurpose agriculture robot across multiple operational parameters. The results indicate high irrigation accuracy and sensor reliability, confirming correct threshold-based decision making. Consistent alert generation and stable

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communication performance demonstrate reliable IoT connectivity and real-time monitoring.

Parameter	Description	Performance (%)
Irrigation Accuracy	Correct activation/deactivation of pump	98
Sensor Accuracy	Accuracy of soil moisture sensing	97
Alert Accuracy	Timely alert generation to user	95
Communication Stability	Reliability of IoT cloud communication	95
Remote Control Success	Successful manual contr ..3…ol via mobile app	96
System Reliability	Continuous stable operation	97
Power Efficiency	Efficient power utilization	94

Table 2:System Performance Evaluation

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Test Case	Soil Moisture Condition	Sensor Value Range	System Action
1	Dry Soil	< Threshold	Pump ON
2	Slightly Dry Soil	Near Threshold	Pump ON
3	Optimal Moisture	Within Range	Pump OFF
4	High Moisture	Above Threshold	Pump OFF
5	Manual Override	User Control	Pump Controlled by User

Table 3:Experimental Test Conditions and System Response

The table conveys that the smart irrigation system is efficient and accurate in pump control, sensor readings, alerts, communication, and remote operation.High system reliability and power efficiency show that it has stable, dependable, and energy, optimized performance that is suitable for automated irrigation applications.

V. CONCLUSION AND FUTURE WORK

This paper presented an IoT-based multipurpose agriculture robot designed to improve farming efficiency through automation, real-time sensing, and remote monitoring. The proposed system integrates soil moisture and environmental sensors with a microcontroller-based control unit to enable intelligent irrigation and automated farming operations. Future work will focus on extending the system with autonomous navigation and advanced path-planning algorithms to improve field coverage. Additional enhancements include integrating more environmental sensors, incorporating solar-powered energy management, and applying machine learning techniques for crop health prediction and yield optimization. The inclusion of mobile robotic swarms and AI- based decision support systems can further improve scalability, adaptability, and resilience in large-scale agricultural environments.

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