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Automatic Multi-Functional Agricultural Robot for Smart Crop

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Abstract: Agriculture is rapidly transforming with the integration of automation and intelligent systems. However, small and marginal farmers still rely heavily on manual labour for irrigation, pesticide spraying and crop monitoring. This work presents the design and development of an Automatic Multi-Functional Agricultural Robot intended for smart crop. The robot is capable of monitoring soil moisture, controlling irrigation automatically, spraying pesticides and navigating fields autonomously. By integrating sensors, a microcontroller and IoT-based monitoring, the system reduces human effort, optimizes water usage and enhances crop productivity. The system is affordable, energy-efficient and suitable for real-time agricultural applications.

Keywords: Smart Agriculture, Agricultural Robot, IoT, Soil Moisture Monitoring, Automation, Sustainable Farming.

I. INTRODUCTION

Agriculture remains one of the most important sectors supporting the Indian economy. Despite technological advancements, many farming practices are still manual, time-consuming and resource-intensive. Farmers often face challenges such as irregular irrigation, excessive pesticide exposure, labor shortages and inefficient monitoring of crop conditions. To address these issues, automation in agriculture has become increasingly important. The Automatic Multi-Functional Agricultural Robot is designed to assist farmers by performing multiple operations in a single compact system. The robot continuously monitors soil and environmental conditions and makes decisions automatically, ensuring optimal crop growth. By reducing dependency on manual intervention, the system promotes efficient and sustainable farming practices.

II. LITERATURE SURVEY

Behera et al (2021) developed an autonomous agricultural robot capable of performing seeding and pesticide spraying operations using embedded controllers and GPS guidance. The robot reduced manual labour and improved field coverage accuracy through programmed path planning and obstacle detection mechanisms.

Chavan et al (2024) proposed a compact multifunctional agricultural robot integrated with ultrasonic sensors for obstacle avoidance and automated navigation. The robot efficiently performed sowing, spraying and soil analysis tasks in smart farming environments.

Kumar et al (2023) introduced a solar-powered agricultural robot designed for weed detection and fertilizer distribution. Image processing techniques enabled selective weed identification, enhancing precision and sustainability in crop management.

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Patil et al (2022) designed a multi-functional farming robot combining ploughing, seed sowing and irrigation modules. Soil moisture sensors were used to automate watering decisions, optimizing water utilization in agricultural fields.

Rahman et al (2023) implemented a machine vision–based agricultural robot for real-time crop health monitoring. The system detected early plant diseases using image classification algorithms, helping reduce potential yield loss.

Ramesh et al (2022) developed an IoT-enabled agricultural robot capable of monitoring environmental parameters and performing precision spraying. Real-time data transmission to a cloud platform improved remote supervision and decision-making.

Verma et al (2022) proposed a wireless-controlled robotic platform integrating ploughing, irrigation and harvesting assistance functions. Field testing demonstrated improved operational efficiency and reduced human intervention.

III. DESCRIPTION OF THE EXISTING SYSTEM

Conventional agricultural systems mainly rely on manual labour and separate farm machinery for ploughing, sowing, irrigation, spraying and harvesting. Each operation is performed individually using different tools, which increases time consumption and labour dependency. Farmers often use tractors for land preparation, manual methods for seed distribution and handheld sprayers for pesticide application. These practices lack precision in seed spacing, fertilizer application and water management.
Semi-automated machines are available, but most of them are designed to perform only a single task and require continuous human supervision. They generally do not include real-time monitoring of soil moisture, crop health or environmental conditions. Due to the absence of automation, intelligent sensing and integrated control, resource utilization becomes inefficient. These limitations reduce productivity and increase operational costs, highlighting the need for a smart multifunctional agricultural robotic system.

Fig.1. Seed sowing robot

IV. DESCRIPTION OF THE PROPOSED SYSTEM

The proposed system is an Automatic Multi-Functional Agricultural Robot designed specifically for crop fields requiring precise root-level chemical spraying. The robot moves between crop rows using BO geared motors controlled through an L298N motor driver, ensuring stable navigation across farmland. A NodeMCU (ESP8266) functions as the central controller, processing inputs from a capacitive soil moisture sensor and a DHT11 temperature and humidity sensor. The chemical spraying unit is connected to a relay-controlled pumping motor that directs agrochemicals through a nozzle positioned near the plant base. By targeting the root zone instead of wide-area spraying, chemical absorption efficiency improves while reducing wastage and environmental contamination. The integrated design supports reliable operation,

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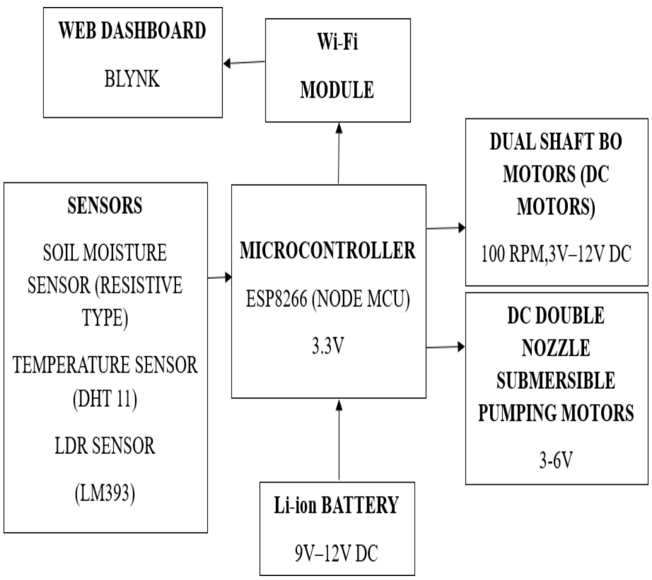
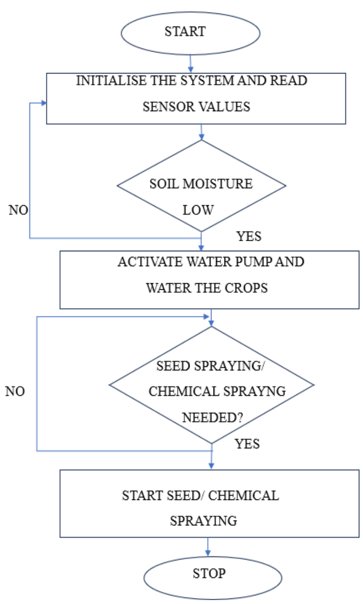
promotes sustainable farming practices and enhances crop productivity in row-based cultivation systems.

Block Diagram:



Block Diagram of Proposed System

Flow Chart:



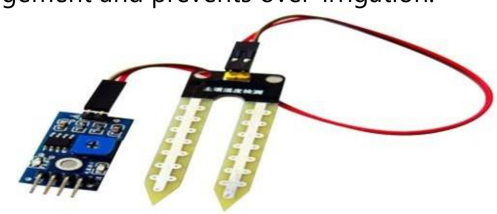
Flow Chart of Proposed System

Hardware Implementation:

The Automatic Multi-Functional Agricultural Robot is developed using embedded electronics, motor control systems and sensor-based monitoring to perform seed sowing, water spraying and chemical spraying efficiently. The hardware architecture is designed to be compact, reliable and suitable for real-time agricultural field conditions.

Hardware Components:

Soil Moisture Sensor: The soil moisture sensor is embedded in the system to measure the moisture content in the soil. When the moisture level drops below the predefined threshold, the controller activates the irrigation mechanism. This ensures efficient water management and prevents over-irrigation.



Soil Moisture Sensor

Microcontroller (NodeMCU ESP8266): At the core of the system is the NodeMCU (ESP8266) microcontroller. It functions as the central processing unit, collecting data from sensors and controlling actuators based on programmed logic. The built-in Wi-Fi capability enables wireless communication for monitoring and remote supervision.

Microcontroller (NodeMCU ESP8266)

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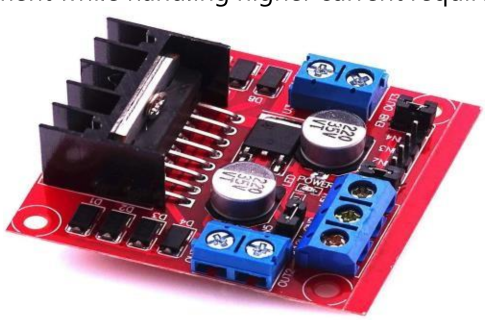
DHT11 Sensor: The DHT11 temperature and humidity sensor continuously monitors atmospheric conditions. These environmental parameters influence seed germination and crop growth, allowing better agricultural decision-making.

DHT11 Sensor

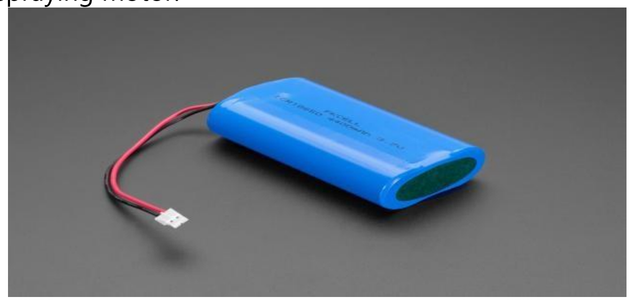
Motors: For mobility, BO geared DC motors are used. These motors provide adequate torque to move the robot across uneven agricultural land. The motors are controlled using an L298N motor driver module, which acts as an interface between the microcontroller and the motors. It enables forward, reverse and directional movement while handling higher current requirements.



L298N motor driver

Battery: Power is supplied through a 12V rechargeable battery, making the robot portable and suitable for rural agricultural fields where continuous grid supply may not be available. Proper wiring using jumper cables ensures secure electrical connections between all components and simplifies maintenance.

A relay module is incorporated to safely control high-power components such as the water pump and spraying motor.



12V Battery

Pumping motor: Water spraying is achieved using a DC water pumping motor connected to a nozzle arrangement. The pump draws water from a storage tank and distributes it evenly across the crop area when activated. Similarly, a chemical spraying motor is used to apply fertilizers or pesticides in a controlled manner, reducing chemical wastage and ensuring uniform coverage.

Pumping Motor

Table 1: Specifications

Sensors	Soil moisture sensor, DHT11 sensor
Microcontroller	NodeMCU(ESP8266)

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Battery	12V(rechargeable type)
Motors	BO motors, L298 motor driver, Pumping motor

V. RESULTS AND DISCUSSION

The proposed Automatic Multi-Functional Agricultural Robot was evaluated in row-based crop fields to assess root-level chemical spraying efficiency and overall performance. The navigation system using BO geared motors and L298N motor driver maintained stable movement between crop rows without disturbing plants. The relay-controlled pumping mechanism delivered chemicals directly to the root zone through a precisely positioned nozzle, ensuring targeted application. Compared to conventional surface spraying, root-directed spraying reduced chemical wastage and minimized drift to surrounding areas. Soil moisture monitoring enabled controlled irrigation, preventing overwatering and supporting balanced crop growth. Environmental readings from the DHT11 sensor assisted in monitoring field conditions. Overall performance demonstrated improved spraying efficiency, reduced resource waste and enhanced crop health, confirming reliability, scalability and cost effectiveness for practical agricultural deployment.

Performance Evaluation

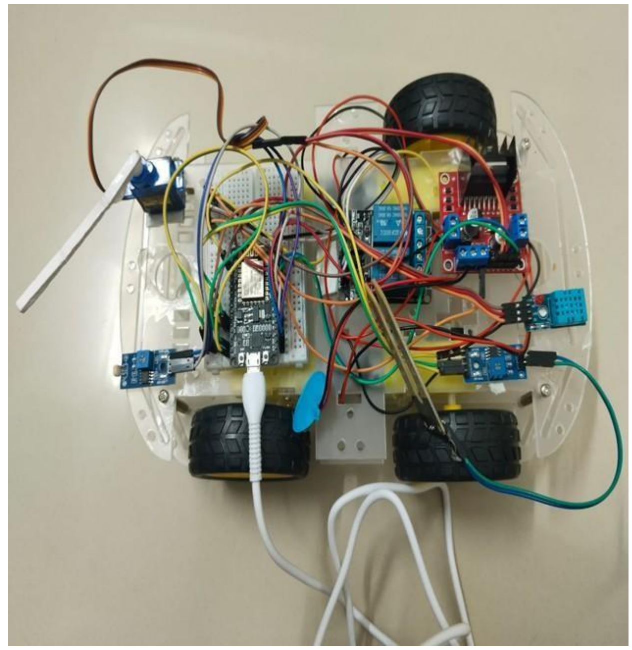

Fig. Hardware Implementation

The performance of the Automatic Multi-Functional Agricultural Robot was evaluated based on spraying accuracy, mobility, response time and resource efficiency. Field testing confirmed that the root-level spraying mechanism delivered chemicals precisely at the base of plants with minimal drift or surface loss. The relay-controlled pumping motor responded quickly to control signals from the NodeMCU, ensuring timely and consistent application. Soil moisture sensing enabled efficient irrigation control, reducing unnecessary water usage. The BO geared motors provided stable navigation between crop rows without plant disturbance. Power consumption analysis showed effective battery utilization for extended operation. Overall evaluation indicates reliable operation, improved spraying efficiency and reduced chemical and water wastage, demonstrating scalability and cost effectiveness in agricultural environments.

VI. CONCLUSION

The Automatic Multi-Functional Agricultural Robot demonstrates an effective approach to precision farming through targeted root-level chemical spraying and sensor-based irrigation control. By integrating NodeMCU (ESP8266), a capacitive soil moisture sensor, DHT11 sensor, L298N motor driver and relay-controlled pumping system, agricultural operations become more accurate and resource-efficient. Direct application of chemicals at the root zone enhances absorption efficiency while significantly reducing wastage and environmental contamination. Uniform seed handling and controlled irrigation further support healthy crop growth and improved yield quality. Stable navigation across crop rows ensures safe field operation without plant damage. The overall design promotes improved farming practices, increases crop productivity and reduces operational costs, while remaining scalable, reliable and cost effective for practical deployment.

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