

Multi-Task Farming Robot with Sensor-Based Smart Sprayer

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Abstract - Agriculture is the backbone of economies in developing nations, yet traditional farming suffers from severe labor shortages, high operational costs, and inefficient pesticide use. This paper presents the design and development of a Multi-Task Farming Robot with Sensor-Based Smart Sprayer capable of autonomously performing ploughing, seed sowing, fertilizer distribution, land leveling, water irrigation, and targeted pesticide spraying on a single robotic platform. The system is governed by an Arduino Uno R3 (ATmega328P) microcontroller interfaced with a TCS3200 color sensor, HC-05 Bluetooth module, relay banks, a 12V DC water pump, 16x2 LCD display, and dedicated motor drives for each farming mechanism. The color sensor continuously monitors plant leaf color and triggers automatic pesticide deployment when diseased foliage - characterized by yellow or dark yellow-brown hues - is detected, thereby reducing chemical consumption and environmental contamination. Wireless remote control via a Bluetooth-enabled mobile application adds operational flexibility. Experimental validation confirms that all six farming operations execute reliably. The proposed system offers a low-cost, scalable solution for small and medium-scale farms aiming to adopt precision agriculture practices.

Key Words: *Multi-Task Farming Robot, Sensor-Based Smart Sprayer, Precision Agriculture, Arduino, Disease Detection, Agricultural Automation.*

I. INTRODUCTION

Agriculture sustains food security and provides livelihood to a vast segment of the global population. In India alone, over 58% of the rural population depends on agriculture. However, the sector faces mounting challenges: shrinking labor availability, rising input costs, and growing environmental pressure from indiscriminate pesticide use. Automation has emerged as a decisive lever to address these constraints. Agricultural robots that integrate multiple field operations onto a single platform promise simultaneous reductions in time, cost, and chemical load while improving yield outcomes [1].

Existing automated systems generally address one operation in isolation - irrigation robots, weeding bots, or dedicated sprayers - creating a fragmented adoption landscape for smallholder farmers. The Multi-Task Farming Robot proposed in this work consolidates six core field operations - soil preparation, seeding, fertilizing, leveling, irrigation, and precision pesticide spraying - within a unified, Bluetooth-controlled robotic frame. The inclusion of a color-sensor-based plant disease detection system distinguishes this design by enabling targeted, condition-triggered chemical application, which contrasts with the blanket spraying approach still common on small farms [2], [11].

The objectives of this work are to: (i) design a single platform executing multiple farming tasks, (ii) automate ploughing, sowing, fertilizing, and leveling, (iii) implement automatic irrigation, (iv) detect plant disease via color sensing and trigger autonomous spraying, and (v) enable wireless control to reduce manual labor and improve farming efficiency. The remainder of this paper is structured as follows: Section II reviews relevant prior work; Section III details system architecture, components, and methodology; Section IV presents experimental results; and Section V concludes the paper.

II. LITERATURE REVIEW

A substantial body of research documents the trajectory from single-purpose farm equipment toward multifunctional robotic systems. Neelambika et al. [9] demonstrated a multifunctional robot for soil digging, seeding, and irrigation that reduced manual intervention on small plots. Karthik S. et al. [7] extended this concept with a rechargeable, wirelessly controlled platform covering ploughing, leveling, and watering operations, confirming the viability of battery-powered multi-task field robots.

On the sensing side, Priya N. et al. [11] showed that color sensors could reliably discriminate diseased leaves from healthy ones based on spectral shift toward yellow or

brown, achieving early disease alerts with low latency. Patil et al. [10] integrated an ESP32 controller with sowing, irrigation, and spraying modules, demonstrating wireless communication efficacy in field environments. Yuan et al. [15] extended disease monitoring to machine vision, while Suresh Kumar V. et al. [14] presented a microcontroller-driven precision sprayer that minimized farmer chemical exposure.

IoT-enabled platforms [8], [12] and AI-assisted systems [4] represent the frontier of smart farming research; however, their cost and infrastructure requirements restrict adoption at the small-farm level. While individual subsystems such as autonomous navigation, disease detection, and multi-task robots have been explored separately, an integrated platform combining sensor-based disease detection with multi-task farming remains limited. The present work bridges this gap using affordable hardware - Arduino, relay modules, a consumer-grade color sensor, and HC-05 Bluetooth - verified under field-proximate conditions.

III. MATERIALS AND METHODOLOGY

A. System Architecture

The robot is built on a stainless-steel frame carrying six functional modules: ploughing blades (front-mounted), a seed-hopper mechanism, a fertilizer hopper, a land-leveling plate, a water spraying nozzle assembly, and the electronic control enclosure. An Arduino Uno R3 serves as the central processing unit, collecting sensor data, interpreting Bluetooth commands, and asserting relay outputs to activate the appropriate actuators. The architecture follows a sense-process-actuate paradigm, as illustrated in Fig. 1.



Fig. 1. Block diagram of the proposed system architecture.

The HC-05 Bluetooth module relays operator commands from a mobile application to the Arduino; relay banks R2-R5 govern the four drive motors enabling omnidirectional movement; Relay 1 controls the water pump; Relay 6

drives the seed-sowing motor; and the TCS3200 color sensor feeds RGB readings to the Arduino for autonomous disease detection. A 16x2 I2C LCD displays real-time direction, pump status, and sensor RGB values.

B. Hardware Components

Table I summarizes the major components. The TCS3200 color sensor converts reflected light intensity from plant leaves into frequency outputs for R, G, and B channels. Threshold calibration established that yellow-diseased leaves register R~249, G~187, B~88 (+30 tolerance), while orange-brown diseased foliage registers R~255, G~216, B~0. These empirical thresholds drive the autonomous spray-on/spray-off logic.

TABLE I. COMPONENTS AND SPECIFICATIONS

Component	Specification	Function
Arduino Uno R3	ATmega328P	Central controller
Color Sensor	TCS3200, RGB	Disease detection
Bluetooth Module	HC-05, 2.4 GHz	Wireless control
DC Motors (x4)	12 V	Robot locomotion
Water Pump	12 V	Spray water/pesticide
Relay Module	5 V, 6-channel	Actuator switching
Battery	12 V Rechargeable	Power supply
LCD Display	16x2, I2C	Status display

C. Mechanical Subsystems

A ploughing tool mounted at the front of the chassis loosens the soil surface as the robot advances, removing weeds and improving aeration. A seed hopper with a motor-driven outlet releases seeds at programmable intervals, while a fertilizer container with a similar outlet distributes nutrients evenly across the soil surface. A leveling blade at the rear smooths the soil after ploughing and seeding to provide a uniform seedbed. The spraying subsystem - comprising a tank, a 12V pump, delivery pipes, and a nozzle - activates either through a manual Bluetooth command or automatically upon disease detection by the color sensor.

D. Sensor-Based Smart Sprayer and Wireless Control

The TCS3200 sensor continuously monitors plant leaf color during operation. The Arduino compares each RGB triplet against disease-color thresholds with a

configurable tolerance of ± 30 counts; a positive match latches the pump relay ON, while a 2,000 ms detection-debounce delay prevents spurious triggering. This event-driven, hardware-efficient design avoids the computational overhead of image processing while remaining responsive at field-traversal speeds.

The HC-05 Bluetooth module pairs with a mobile application to issue integer-coded movement and actuator commands (Forward=1, Backward=2, Left=3, Right=4, Stop=5, Seed Open/Close=9/10), which the Arduino translates into relay-switching patterns. The firmware, developed in the Arduino IDE (C/C++), uses Wire.h and LiquidCrystal_I2C.h for the LCD, a TCS3200 driver for the color sensor, and SoftwareSerial.h for Bluetooth UART communication. The main loop runs at 500 ms intervals, sequentially parsing Bluetooth commands, acquiring RGB data, evaluating color thresholds, and refreshing the LCD.

IV. RESULTS AND DISCUSSION

Each subsystem was tested independently under natural lighting before integrated field trials on prepared soil. Table II summarizes the experimental outcomes; all operations were confirmed as operationally successful and repeatable across multiple trials.

TABLE II. EXPERIMENTAL OBSERVATIONS

Operation	Observation	Status
Ploughing	Soil loosened uniformly	Successful
Seed Sowing	Seeds at regular intervals	Successful
Fertilizer Distribution	Nutrient spread evenly	Successful
Land Leveling	Smooth, uniform seedbed	Successful
Water Spraying	Even irrigation coverage	Successful
Disease Detection & Spray	Diseased leaf correctly flagged	Successful
Bluetooth Control	All commands executed correctly	Successful

The ploughing mechanism penetrated the test soil bed to a consistent depth, producing a visibly aerated surface. Seed spacing, governed by timed hopper-motor actuation, averaged 12-15 cm at the test traverse speed - adequate for most row-crop configurations - while the fertilizer

hopper released granular material evenly across the path width.

The smart-spray subsystem demonstrated strong performance: the TCS3200 sensor correctly classified all yellow- and orange-brown-leaf test samples as diseased, activating the pump relay within one 500 ms sensing cycle with response latency under 200 ms. No false positives were recorded for healthy green foliage under natural illumination, and the 2-second debounce suppressed spurious double-triggering observed during early calibration. This selective activation pattern indicates a potential 30-50% reduction in pesticide consumption relative to blanket spraying.

Bluetooth control remained stable up to approximately 10 meters in open air with no perceptible command latency. Battery endurance under continuous full-load operation was approximately 45 minutes per charge cycle, consistent with small-plot tasks. Key limitations include sensitivity of color-based detection to ambient lighting, and suitability primarily for flat or gently sloped terrain.

V. CONCLUSION

A compact, low-cost, multi-task farming robot integrating ploughing, seeding, fertilizing, leveling, irrigation, and sensor-driven precision pesticide spraying has been successfully designed, fabricated, and experimentally validated. The Arduino Uno R3 microcontroller, aided by a TCS3200 color sensor and HC-05 Bluetooth module, delivers reliable autonomous disease detection and remote operational control within a single robotic platform.

Experimental results confirm that all farming operations execute without failure, with the color-sensor spray system achieving reliable detection accuracy on all test leaf samples. The system reduces dependence on manual labor, eliminates blanket chemical application, and provides an accessible entry point into precision agriculture for small and medium-scale farmers.

Future enhancements will explore GPS-guided autonomous navigation, solar energy harvesting for extended operational autonomy, IoT-based remote field monitoring, and replacement of the color sensor with a deep-learning vision module to broaden the range of detectable diseases beyond color-based symptoms.

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