

# SMART AGRICULTURE ROVER USING LORA COMMUNICATION AND ESP32-CAM FOR PRECISION SPRAYING

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## Abstract :

Modern agriculture requires intelligent and economical systems capable of reducing manual effort and improving spraying efficiency. Traditional pesticide spraying methods expose farmers to harmful chemicals and often result in uneven spraying and chemical wastage. The proposed smart agriculture rover uses LoRa communication, STM32 controllers, HC-05 Bluetooth module, and ESP32-CAM technology to perform wireless precision spraying and remote field monitoring. The mobile application sends movement and spraying commands through Bluetooth communication to the HC-05 module connected to the transmitter-side STM32 controller. The STM32 processes the received commands and transmits them wirelessly through the LoRa module. The receiver-side LoRa module receives the transmitted data and sends it to another STM32 controller mounted on the rover. Based on the received commands, the rover performs forward, backward, left, right, spray ON, and spray OFF operations through the L298N motor driver and relay-controlled pump system. The ESP32-CAM module provides live video streaming for real-time monitoring and navigation assistance. Experimental testing demonstrated stable rover operation and reliable communication within approximately 1–2 km range in open-field conditions. The proposed system reduces human exposure to pesticides, minimizes chemical wastage, and provides a low-cost smart farming solution suitable for precision agriculture applications.

## Keywords:

Smart Agriculture, LoRa Communication, ESP32-CAM, HC-05 Bluetooth Module, Precision Spraying, STM32, Agricultural Automation.

## I. INTRODUCTION

Agriculture is one of the most important sectors contributing to food production and economic growth. However, many agricultural operations are still performed manually, especially pesticide spraying and field monitoring activities. Farmers are often directly exposed to harmful pesticides during spraying operations, which may affect their health and increase operational risk. Manual spraying also causes excessive chemical usage, uneven distribution, and increased labor requirements. Therefore, there is a growing demand for intelligent agricultural automation systems capable of improving operational efficiency and reducing human effort.

Recent advancements in embedded systems, wireless communication, and IoT technology have enabled the development of smart farming systems capable of performing agricultural operations remotely and efficiently. Wireless communication technologies such as Bluetooth, Wi-Fi, ZigBee, and LoRa are widely used in

agricultural automation applications. Among these technologies, LoRa communication provides long communication range with low power consumption, making it highly suitable for rural agricultural environments where internet connectivity may not be available.

The proposed smart agriculture rover combines wireless control, precision spraying, and live monitoring into a single integrated platform. The system uses a mobile application to control rover movement and spraying operations. Commands generated from the mobile application are transmitted through the HC-05 Bluetooth module connected to the transmitter-side STM32 controller. The STM32 processes the commands and transmits them through the LoRa module to the receiver-side rover system. The rover performs movement and spraying operations according to the received instructions. An ESP32-CAM module provides real-time video streaming support for field monitoring and rover navigation.

The developed system aims to reduce human exposure to pesticides, improve spraying precision, reduce pesticide wastage, and provide a low-cost smart agriculture solution suitable for modern precision farming applications.

## II. LITERATURE REVIEW

Several researchers have proposed smart agriculture systems using embedded systems, IoT technology, robotics, and wireless communication for agricultural automation. Existing agricultural robots mainly focus on crop monitoring, irrigation management, environmental sensing, and automated spraying operations.

Patil et al. developed a smart pesticide spraying system using IoT technology to improve spraying efficiency and reduce human effort. Although the system improved automation, it depended heavily on internet connectivity, limiting its practical use in remote agricultural areas.

Wang et al. designed an agricultural robot capable of automated movement and crop monitoring. The developed system successfully reduced manual labor and improved monitoring efficiency. However, the system involved complex implementation and higher hardware cost.

Kumar et al. proposed a wireless monitoring system for agricultural field applications using sensor networks and wireless communication. The system provided long-range communication but lacked integrated spraying functionality and live monitoring support.

Sharma et al. developed an IoT-based agriculture automation system with environmental monitoring and low-power operation. Although the system improved automation capability, it did not support wireless rover control and remote pesticide spraying.

Lee et al. introduced an automated wireless sprayer for precision farming applications. The system improved spraying efficiency but required high maintenance and frequent servicing.

From the literature survey, it is observed that most existing systems focus on either monitoring or automation individually. Very few systems integrate wireless rover movement, long-range communication, live monitoring, and precision spraying into a single compact platform. The proposed smart agriculture rover addresses these limitations by integrating mobile application control, HC-05 Bluetooth communication, LoRa wireless transmission, ESP32-CAM monitoring, and precision spraying into a cost-effective smart farming solution.

### III. SYSTEM DESIGN

The developed smart agriculture rover consists of transmitter and receiver sections designed for wireless agricultural operation. The transmitter section includes a mobile application, HC-05 Bluetooth module, STM32 microcontroller, and LoRa transmitter module. The mobile application is used by the operator to generate directional and spraying commands such as forward, backward, left, right, spray ON, and spray OFF. These commands are transmitted through Bluetooth communication to the HC-05 module connected with the STM32 controller.

The STM32 controller processes the received Bluetooth data and sends the commands to the LoRa transmitter module for long-range wireless communication. The LoRa transmitter wirelessly transmits the control signals to the receiver section mounted on the rover.

The receiver section includes a LoRa receiver module, STM32 controller, L298N motor driver, DC gear motors, relay-controlled spray pump, and ESP32-CAM module. The LoRa receiver receives the transmitted signals and forwards them to the STM32 controller. The STM32 decodes the received instructions and generates appropriate control signals for rover movement and spraying operation.

The L298N motor driver controls the DC motors connected to the rover wheels and enables movement in forward, backward, left, and right directions. A relay module controls the spraying pump for pesticide spraying operations. The ESP32-CAM module continuously provides live video streaming support for field monitoring and navigation assistance. The complete system is powered using rechargeable batteries, making the rover portable and suitable for outdoor agricultural environments.

### IV. PROPOSED METHODOLOGY

The proposed smart agriculture rover operates using embedded control systems and wireless communication technology. Initially, the user operates the mobile application to send movement and spraying commands. The commands generated from the mobile application are transmitted wirelessly through Bluetooth communication to the HC-05 Bluetooth module connected with the transmitter-side STM32 controller.

The STM32 controller processes the received Bluetooth data and generates corresponding digital control instructions. These instructions are transmitted through the LoRa communication module for long-range wireless operation. The LoRa transmitter sends the wireless data signals to the receiver-side LoRa module mounted on the rover.

The receiver-side STM32 controller receives and decodes the transmitted data from the LoRa receiver module. Based on the decoded instructions, the controller generates appropriate control signals for the L298N motor driver and relay module.

The L298N motor driver controls the DC motors connected to the rover wheels and enables rover movement in forward, backward, left, and right directions. When the spraying command is received, the STM32 activates the relay module, which switches ON the pesticide spraying pump. Similarly, the spray OFF command deactivates the relay and stops spraying operation.

The ESP32-CAM module continuously provides live video streaming support during rover operation. The real-time monitoring system helps the operator navigate the rover efficiently and monitor agricultural field conditions remotely. The developed methodology improves operational safety, reduces pesticide wastage, minimizes human labor, and enhances agricultural spraying efficiency.

## V. RESULTS AND DISCUSSION

The developed smart agriculture rover was experimentally tested under laboratory and open-field conditions to evaluate wireless communication performance, rover movement stability, spraying efficiency, and monitoring capability.

The LoRa communication modules achieved stable wireless communication within approximately 1–2 km range in open-field environments. The transmitted commands were received successfully with minimal delay, enabling smooth rover operation.

The rover successfully performed forward, backward, left, and right movements according to commands received from the mobile application. The L298N motor driver provided stable control of DC motors and smooth directional movement.

The relay-controlled spraying mechanism successfully performed controlled pesticide spraying operations. The developed spraying system minimized chemical wastage by activating the spray pump only when spraying commands were received.

The ESP32-CAM module successfully provided real-time video streaming during rover operation. The live monitoring system improved navigation accuracy and enabled remote field observation without direct human presence in pesticide-affected areas.

The developed prototype demonstrated that the integration of Bluetooth communication, LoRa wireless transmission, embedded control systems, and live monitoring technology can provide an effective and economical solution for precision agriculture applications.

## VI. CONCLUSION

The developed smart agriculture rover using LoRa communication and ESP32-CAM technology demonstrated reliable performance for wireless agricultural spraying and remote field monitoring applications. The system successfully integrated mobile application control, HC-05 Bluetooth communication, LoRa wireless transmission, rover movement control, precision spraying, and live monitoring into a single compact platform.

The developed rover reduces manual labor and minimizes direct human exposure to harmful pesticides, thereby improving operational safety. The relay-controlled spraying mechanism improves spraying precision and reduces unnecessary pesticide wastage. The ESP32-CAM module provides effective real-time monitoring support for agricultural field observation and rover navigation..

Experimental testing confirmed reliable communication performance within approximately 1–2 km range and stable rover movement under agricultural operating conditions. The proposed system is economical, portable, and suitable for rural agricultural environments where internet connectivity may be limited.

In future work, the system can be improved by integrating GPS navigation, obstacle detection sensors, AI-based crop analysis, solar charging systems, and autonomous navigation algorithms for fully automated precision farming applications.

**Table 1. Literature Review Comparison**

Author	Research Area	Observation	Limitation
Patil et al.	Smart Spraying	Improved spraying efficiency	Internet dependency
Wang et al.	Agriculture Robot	Reduced human effort	Complex implementation
Kumar et al.	Wireless Monitoring	Long-range operation	Higher cost
Sharma et al.	IoT Agriculture	Low power operation	Limited monitoring
Lee et al.	Wireless Sprayer	Automated operation	High maintenance

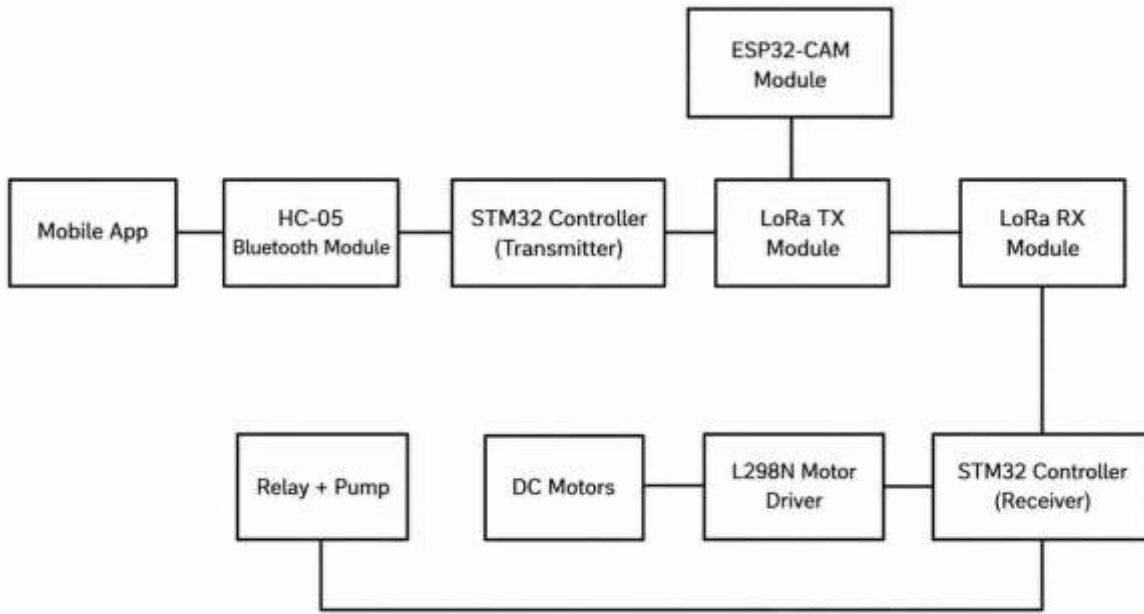


Figure 1. System Block Diagram of Smart Agriculture Rover

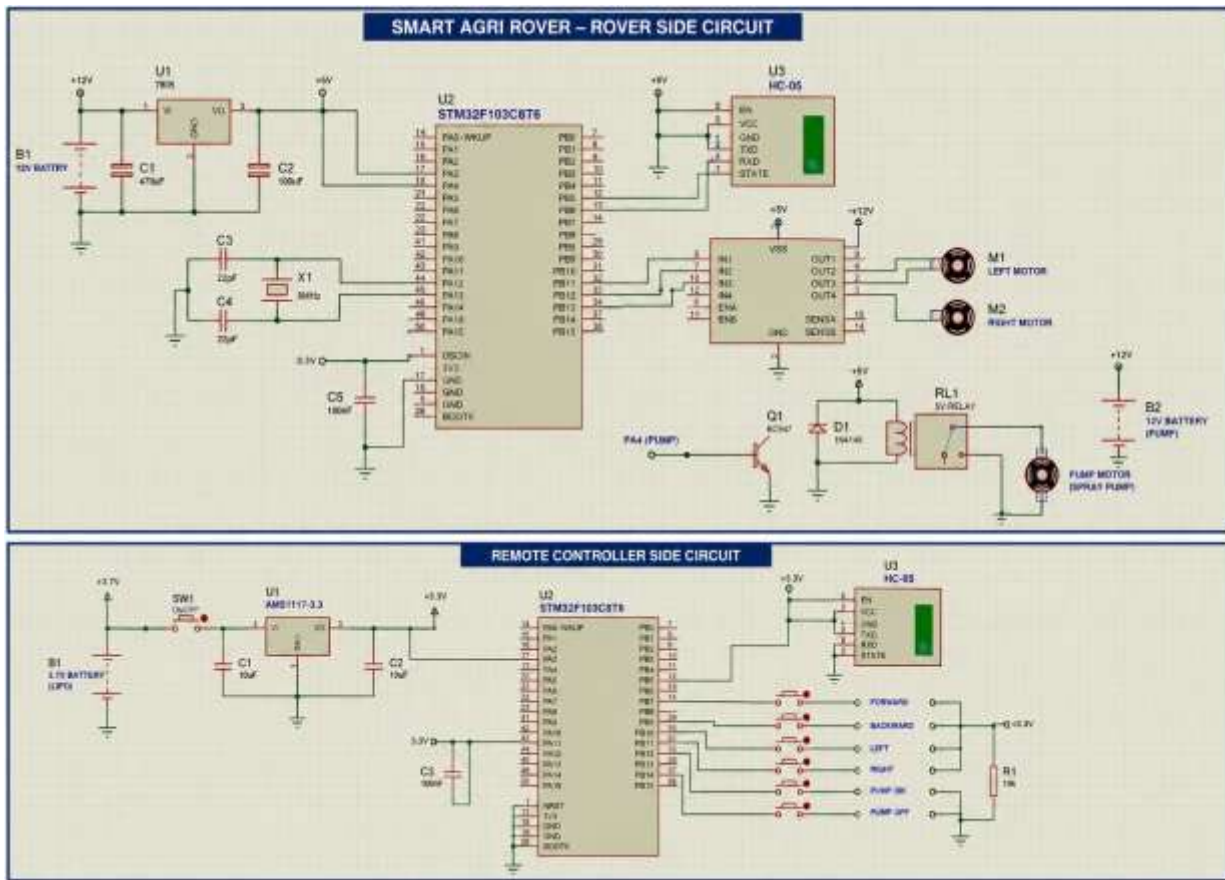


Figure 2. Rover Side and Remote Controller Side Circuit Diagram of Smart Agriculture Rover

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