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FarmBot - Smart Pesticide Spraying System

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Abstract: The design and development of a low-cost agricultural rover called Farm-bot is presented in this paper with the goal of helping farmers apply pesticides safely and effectively. An ESP32 micro-controller powers the system, which uses a relay module to run a pump motor and an L298N motor driver to control four DC motors in a 4WD setup. To ensure even distribution, the pesticide is sprayed through a nozzle boom and kept in a 2-liter tank. A 12V DC battery powers the entire system, and Proteus is used for simulation while the Arduino IDE is used to construct the control logic. CAD programs like Open SCAD and Fusion 360 were used to design the rover's chassis. The prototype is affordable for small and medium-sized farmers, with an estimated cost of ₹8,000 to ₹10,000. Future automation and sensor integration for autonomous field navigation are built upon this manually operated concept.

Index Terms - ESP32, Precision Agriculture, Farm-bot, Insecticide Sprayer, 4WD Rover, and Embedded System.

I. Introduction

Many developing economies, like India, where a sizable section of the populace makes their living from farming, rely heavily on agriculture. Even though technology has advanced in many areas, manual labor is still a major part of rural agriculture. The hand application of pesticides is one of the most dangerous and time-consuming farming activities. Farmers frequently come into direct contact with dangerous chemicals, which can pose a major risk to their health and the environment. Furthermore, manual spraying distributes pesticides unevenly, which reduces crop protection effectiveness and causes waste.

Robotics and automation present a viable way to overcome these obstacles. The development of agricultural robots, or "AgriBots," as a result of the integration of mechatronics and embedded systems in agriculture, can help farmers carry out dangerous and repetitive activities more precisely and safely. In order to automate insecticide spraying at a reasonable cost, this study describes the design and development of a manually operated agricultural rover called Farm-bot. The ESP32 micro-controller, which powers the suggested system, regulates both the spraying mechanism and the rover's movements. To guarantee steady mobility on uneven terrain, it makes use of four DC motors set up in a 4WD configuration. Using a nozzle boom, a relay-controlled pump evenly spreads pesticide after drawing it from a 2-liter tank. The Farm Bot, which was created with affordability and usefulness in mind, lays the groundwork for next developments like sensor integration and self-navigating precision farming applications.

II. LITERATURE REVIEWTYPE

Using robotics and the Internet of Things, a number of researchers and developers have investigated automated spraying systems.

- An Arduino-based pesticide sprayer with DC motors and ultrasonic sensors for obstacle detection was demonstrated by Naveen Kumar in 2022. Nevertheless, the technology was not capable of wireless communication.
- An IoT-enabled smart sprayer robot with Wi-Fi was shown by Sagar Patel and Amit Joshi (2023), but because it used a Raspberry Pi, it was expensive.
- Rahul Verma (2021) created a robot that could spray using Bluetooth, but it had trouble with range.

In contrast, Farm-Bot's ESP32 microcontroller has dual-core processing, Bluetooth and Wi-Fi built in, and a lower power consumption, which makes it perfect for both manual and semi-automated control systems. Additionally, this project places a strong emphasis on simplicity and modularity, enabling components to be improved or replaced with little technical expertise.

III. OBJECTIVES

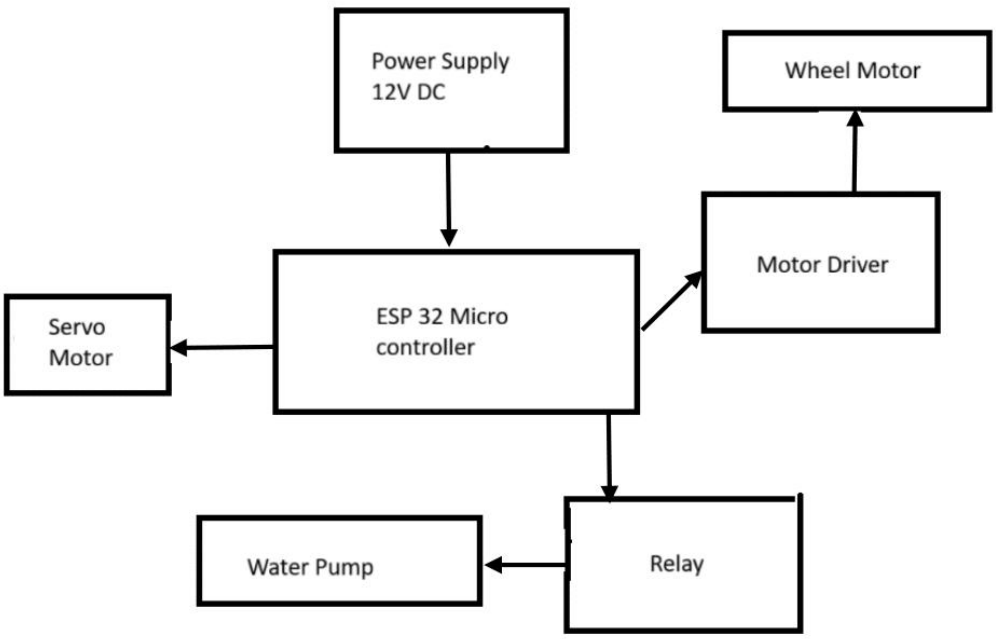
This research project's primary goals are:

1. To create and test a low-cost, four-wheeled pesticide-spraying agricultural rover.
2. To use basic input switches and an ESP32 to achieve manual control.
3. To use Proteus software to design and simulate the entire electrical circuit.
4. To use Fusion 360 and Open SCAD tools to create a chassis that is mechanically stable.
5. To assess spraying dependability, affordability, and efficacy in practical settings.
6. To investigate upcoming developments for IOT integration and autonomous control.

IV. SYSTEM DESIGN

A. Block Diagram Description

The following are the main building blocks of the Farm-Bot's architecture:



1. The fundamental component of the system that regulates movement and spray functioning is the Control Unit (ESP32).
2. Four DC motors, two on each side, are controlled by the motor driver (L298N).
3. Relay Module: ESP32 controls the ON/OFF switch for the pesticide pump.
4. Power Supply: The ESP32 receives 5V from a voltage regulator, while motors and the pump are powered by a 12V lead-acid battery.
5. Pump & Nozzle Assembly: Uses a pressured flow to distribute insecticide uniformly.
6. The mechanical chassis supports the pesticide tank and houses all of the hardware.

B. Circuit Design

The circuit was created and tested using Proteus Design Suite. The L298N inputs (IN1–IN4) for motor control and the relay input for pump control are connected to the ESP32 GPIO pins. Capacitors and flyback diodes are used to prevent voltage spikes. Stable functioning under variations in motor load is guaranteed by the power supply design.

C. Mechanical Structure

For increased stability on difficult farm terrain, the rover is equipped with a 4-wheel drive (4WD) system. Reinforced plastic and lightweight metal are used to construct the chassis. For even weight distribution, the two-liter pesticide tank is positioned in the middle. Depending on the type of crop, the operator can modify the spray height thanks to the movable boom arm that holds the spray nozzles.

V. SOFTWARE AND CONTROL LOGIC

A. ESP32 Programming

The Arduino IDE was used to program the ESP32. The following actions are taken by the primary control algorithm:

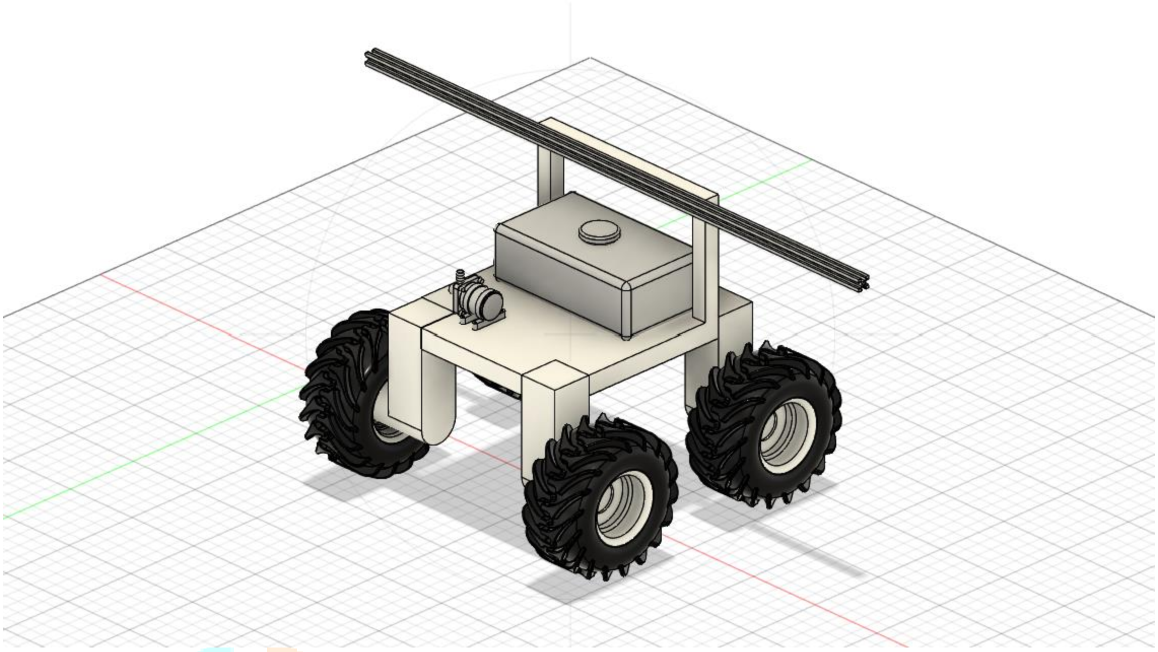
1. Set up the GPIOs for manual switches, relays, and motor control.
2. Read data from the forward, backward, left, and right direction control switches.
3. Using the L298N module, generate PWM signals to regulate motor speed.
4. Depending on the input from the spray button, turn the pump on or off.
5. Install safety interlocks to stop the pump from running when it is not moving.

B. Simulation Testing

The circuit was simulated in Proteus prior to physical prototyping in order to confirm relay activation time and motor control signals. In order to prevent hardware damage during actual testing, simulation graphs verified proper PWM production and voltage response.

C. 3D Model of FarmBot Rover

The complete 3D model of the Farm-Bot was designed using Fusion 360 to visualize the chassis, tank placement, and motor mounting before fabrication. The simulation helped validate mechanical clearances, weight distribution, and component fitting, ensuring a more accurate and reliable physical prototype.



VI .RESULTS AND ANALYSIS

A. Experimental Setup

On a 10-by-5-meter agricultural plot with grass and dirt surfaces, the Farm-Bot prototype was put together and put through testing. During the test, the rover was operated at various speeds while the spray coverage was monitored.

B. Cost Analysis

Component	Quantity	Cost (INR)
ESP32 Dev Board	1	450
L298N Driver Module	1	200
DC Motors (12V)	4	1600
Relay Module	1	100
Pump Motor (12V)	1	750
Nozzle and Tubing	1 set	300
Battery (12V 7Ah)	1	1200
Chassis & Frame	1	2500
Miscellaneous	-	1000
Total Cost	-	~₹8,100

VII. DISCUSSION

The created prototype effectively illustrates how inexpensive automation may greatly increase farm safety and productivity. Although manual operation is less efficient than autonomous robots, it guarantees accessibility for farmers who are not familiar with sophisticated electronics or programming.

The rover achieved even spray dispersion and performed dependably over rugged terrain throughout testing. However, motion stability may be impacted by uneven terrain, indicating the necessity for larger wheels or suspension systems in subsequent versions. Additionally, semi-autonomous mobility and obstacle avoidance may be made possible by the addition of sensors (such as infrared or ultrasonic).

Another area for development was power optimization; switching from DC motors to brushless motors could prolong battery life. Future improvements could potentially handle wireless communication and motor control simultaneously thanks to the ESP32's dual-core capability.

VIII. FUTURE SCOPE

The Farm-Bot features a modular framework built for progressive technical upgrades:

1. IoT Integration:Wireless control of the ESP32 is possible through a dashboard or mobile app thanks to its integrated Wi-Fi. This allows for real- time rover location tracking, pump status monitoring, and battery voltage monitoring.

2. Self-Driving Navigation:Farm-Bot can autonomously cover fields, identify impediments, and follow predetermined routes using GPS and ultrasonic sensors.

3. Target Spraying Using AI:In order to save water and pesticides, future iterations might employ computer vision to identify crops contaminated by pests and spray only the impacted areas.

4. Solar-Powered Function:By adding a solar panel to the chassis, you can decrease your reliance on grid charging and increase operating time.

5. Seed and Fertilizer Dispensing:Farm-Bot can also be used for automated seeding or fertilizer application by swapping out the spray module.

IX.CONCLUSION

The Farm-Bot project serves as an example of how affordable embedded technologies might transform conventional farming methods. The ESP32-based control system offers scalability, versatility, and effective operation. At a fraction of the price of commercial robotic sprayers, the prototype accomplished consistent spraying, reliable movement, and easy-to-use manual control.

The research demonstrates the effectiveness of combining simulation tools, embedded control, and mechanical design to provide practical agricultural solutions. To create Farm-Bot an intelligent, self-operating agricultural aid, future research will concentrate on complete automation utilizing IOT and computer vision.

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