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Automatic Plant Watering System Using Arduino UNO and Soil Moisture Sensor

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ABSTARCT

The design and execution of an autonomous smart pesticide spraying system for effective agricultural field operations are presented in this study. The ESP32 microprocessor at the center of the suggested system uses a four-wheel drive mechanism driven by an L293D motor driver to coordinate the sprayer's navigation, allowing for precise movement in every direction. The spraying process is controlled by a specialized PSI motor, which enables exact control over pesticide discharge in accordance with operational requirements. An ESP32CAM module is added to offer real-time video streaming and remote supervision in order to enhance monitoring and navigation. Solar energy powers the entire system, guaranteeing sustainable and environmentally friendly operation in outdoor farming settings. The technology lowers environmental effect, improves application precision, and decreases pesticide abuse by combining autonomous navigation, controlled spraying, and real-time visual input. Experimental testing demonstrates the suggested sprayer's viability for use in contemporary precision agriculture by confirming its dependability and efficacy.

Keywords: Automatic Plant Watering System, Arduino UNO, Soil Moisture Sensor, ESP32 Microcontroller, Smart Agriculture, Automated Irrigation, IoT-Based Monitoring, Precision Agriculture, Water Pump Control, Sustainable Farming.

I. INTRODUCTION

The Intelligent Smart Data Recorder is an innovative vehicle safety technology developed to improve accident detection, emergency response, and post-accident analysis. With the rapid increase in vehicle usage, road accidents have become a major public safety concern, often leading to severe consequences due to delayed emergency assistance. To address this challenge, the proposed system functions as a smart black box for vehicles, providing continuous monitoring and intelligent accident detection.

The system integrates Internet of Things (IoT) sensors, a Global Positioning System (GPS), and a microcontroller to track critical vehicle parameters such as speed, impact force, location, and sudden deceleration. An Automatic Accident Notification System (AANS) detects accidents in real time and instantly alerts nearby emergency services, significantly reducing response time and increasing survival rates.

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In addition to real-time alerts, the system records sensor data and video footage using an SD card and cloud storage. This information supports detailed post-accident investigations, helps authorities understand accident causes, enhances vehicle security, and enables data-driven strategies for accident prevention. By combining real-time monitoring with intelligent data analysis, the proposed system contributes to improved road safety and proactive emergency management.

Conventional pesticide spraying techniques frequently have problems such as overuse of chemicals, inconsistent application, damage to the environment, and higher operating costs. Over-application and uneven coverage are common outcomes of manual spraying methods, which can cause chemical runoff and inadvertent damage to nearby ecosystems and nontarget animals. Efficient and sustainable options that lessen these detrimental effects while preserving crop output are becoming more and more necessary as agricultural practices continue to evolve. By combining automation, sensing technology, and intelligent control systems to maximize resource use, precision agriculture has developed as a successful strategy to address these issues.

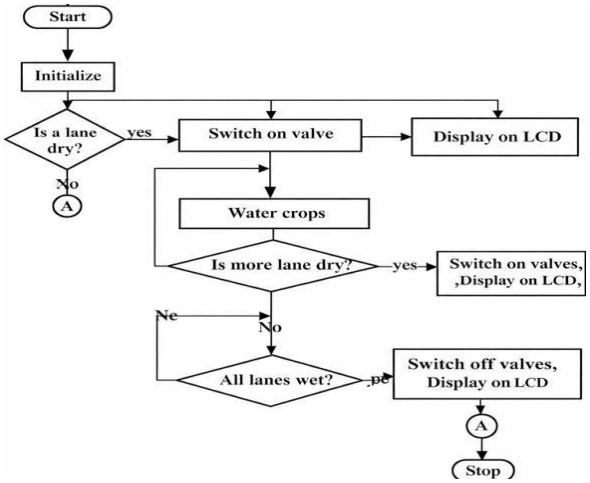


Fig. 1. Algorithm of Automatic Plant Watering System using Arduino UNO and Soil Moisture Sensor.

Self-navigating sprayers are one of these innovations that offer a promising answer since they allow for precise pesticide application, autonomous mobility, and real-time monitoring. These technologies guarantee consistent spraying throughout agricultural fields, limit pesticide waste, and lessen human interaction. The development of a self-navigating smart sprayer with an integrated hardware–software architecture for precise and controlled pesticide delivery is the main topic of this study.

The ESP32 microcontroller, which serves as the primary control unit for overseeing navigation and spraying operations, is the focal point of the system. The sprayer is powered by a solar energy source to enable continuous and environmentally friendly operation in outdoor settings, supporting sustainable field deployment. Four DC motors powered by an L293D motor driver integrated circuit enable the sprayer to move forward, backward, left, and right with exact directional control. The suggested technology is appropriate for contemporary precision agriculture applications since it allows autonomous field navigation with increased accuracy and operational dependability.

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II. LITURATURE SURVEY

Significant research has been conducted in the fields of smart farming, autonomous agricultural vehicles, and IoT-based control systems due to the growing emphasis on sustainable and effective agricultural methods. Conventional pesticide application techniques frequently lead to overuse of chemicals, uneven spraying, and a heavy reliance on manual labor. Recent research has concentrated on creating intelligent, self-navigating agricultural devices that can carry out precise, regulated activities in order to address these issues.

Modern agricultural machinery relies heavily on autonomous navigation and path-planning algorithms. In order to help agricultural vehicles function well in both structured and unstructured field contexts, Zhou and He [?] looked into a variety of navigation techniques. In order for autonomous pesticide sprayers to provide uniform coverage while preventing crop damage, their work emphasizes the significance of dependable path planning for row based agricultural operations.

The transformation of traditional agriculture into smart agriculture has been greatly aided by the use of Internet of Things (IoT) technologies. IoT-based systems can automate farming tasks, minimize labor needs, and maximize the use of natural resources, according to studies by Kumar et al. [?] and Rahman et al. [?]. These systems provide a solid technological basis for controlled pesticide spraying systems by integrating sensors, microcontrollers, and wireless communication technologies to continually monitor field conditions and control actuators.

For smart farming applications, a number of researchers have suggested integrated Io based systems. An adaptive IoT-enabled architecture that facilitates intelligent decision making and real-time data collection was presented by Kakamoukas et al. [?]. In a similar vein, Citoni et al. [?] addressed the application of IoT and LoRaWAN technologies for largescale agricultural systems, highlighting benefits like long-range communication and low power consumption that are ideal for autonomous field equipment.
In autonomous agricultural systems, energy efficiency and system dependability are crucial factors. Sadowski and Spachos demonstrated the viability of utilizing renewable energy sources to support field-deployed smart devices by presenting a solar-powered IoT-based agricultural monitoring system. The operational independence and dependability of selfnavigating pesticide sprayers are improved by such energy-efficient technologies.

Numerous studies have also been conducted on the use of autonomous robots in agricultural tasks. In order to demonstrate the efficiency of robotics and automation in carrying out specific agricultural chores, Kumar et al. [?] created an autonomous gardening rover combined with intelligent plant recognition algorithms. These methods are directly applicable to controlled pesticide spraying, where chemical waste can be greatly decreased through selective application.

Recent studies also highlight the integration of digital technologies, wireless sensor networks, and automation to improve monitoring and management in agricultural contexts. All of these studies show

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that the efficiency, precision, and sustainability of pesticide application may be significantly increased by integrating autonomous navigation, IoT-based monitoring, and controlled actuation.

The creation of a self-navigating sprayer for regulated pesticide application is clearly a promising breakthrough in contemporary agriculture, according to the studied literature. The suggested system can minimize labor dependency, improve environmentally sustainable farming methods, and reduce pesticide abuse by combining autonomous navigation, IoT-enabled control mechanisms, and effective spraying units.

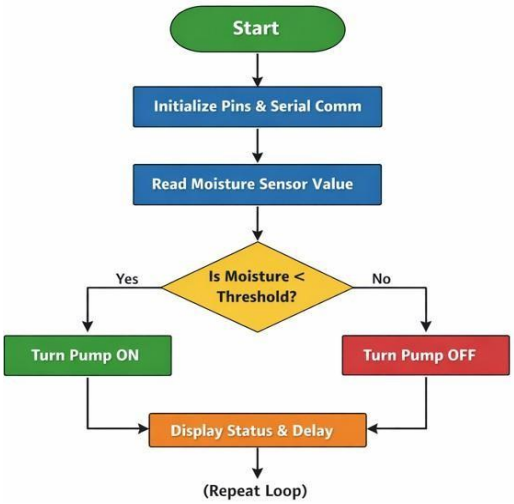


Fig. 2. Flow Chart of Automatic Plant Watering System using Arduino UNO and Soil Moisture Sensor.

III. PROPOSED SYSTEM

The suggested system for the creation of a self-navigating smart sprayer is intended to guarantee operator safety and environmental sustainability while enabling controlled and effective pesticide application. By automating the spraying process and lowering human involvement, the technology minimizes chemical waste and health risks.

An ESP32 microcontroller, which serves as the main control unit and synchronizes all system functions, is at the center of the system. Through a relay module, the ESP32 microprocessor regulates the PSI motor's activation and deactivation, guaranteeing accurate and timely pesticide spraying. By limiting human exposure to dangerous chemicals and drastically lowering excessive application and environmental pollution, this regulated operation aids in optimizing pesticide usage.

The ESP32 uses an L293D motor driver IC to control four DC motors in order to achieve autonomous navigation. The sprayer can travel forward, backward, left, and right thanks to this motor control system, making it easy to navigate over a variety of field layouts and terrain conditions. Because of its mobility, the system is ideal for large agricultural fields where manual spraying requires a lot of time and effort. The system incorporates an ESP32-CAM module for real-time monitoring. This module enables remote supervision by providing real-time visual feedback of the sprayer's environment and operational state.

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By allowing observation from a safe distance, this function improves user safety and increases precision during operation.

A solar energy unit coupled to a 12V battery powers the entire system, guaranteeing a selfsufficient power supply for every electrical component. By removing reliance on outside power, this renewable energy source supports long-term field deployment and permits continuous operation in isolated agricultural settings.

In summary, the suggested smart sprayer system provides an automated, energy-efficient, and remotely monitored way to apply pesticides. The technology facilitates precision agriculture and encourages safer and more effective agricultural methods by combining autonomous navigation, real-time visualization, and renewable energy.

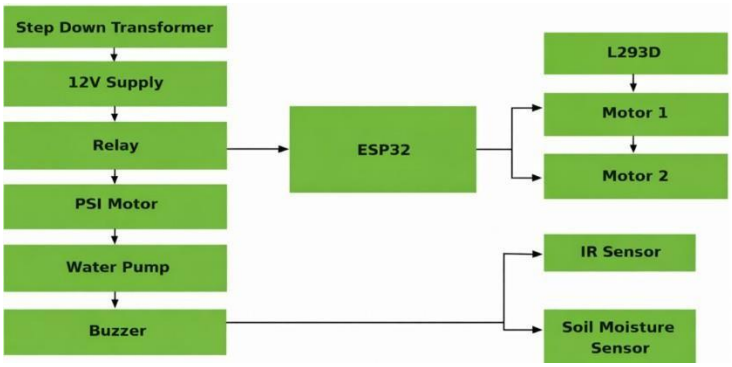


Fig. 3. Block Diagram of Pesticide Sprayer.

The central control unit of the smart pesticide sprayer system is the ESP32 microcontroller, which is seen in Fig. 2. It is in charge of wireless connectivity, real-time monitoring, pesticide spraying, and vehicle movement management. In order to minimize chemical waste and human exposure, the system is built to autonomously tour agricultural areas and precisely apply pesticides.

Four DC motors that are managed by the ESP32 via an L293D motor driver IC are used to move the vehicle. Bidirectional motor control for forward, backward, left, and right movements is made possible by the L293D's H-bridge function. Smooth and accurate navigation is made possible via the ESP32's Pulse Width Modulation (PWM) signals, which control motor speed and direction.

Additionally, the ESP32 uses a PSI motor that is connected via a relay module to regulate the pesticide spraying mechanism. The high-current motor may be safely turned on and off thanks to the relay's electrical separation. Targeted pesticide application is made possible by wireless spraying commands transmitted via a Bluetooth controller application.

A camera module is interfaced with the ESP32 to feed live video for real-time monitoring, enabling remote navigation and spraying operations supervision. The ESP32-based system is effective, dependable, and appropriate for precision agriculture since it integrates wireless control, motor driving, spraying control, and live monitoring.

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2025, Volume 6 Issue 4
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Fig. 4. ESP32 Microcontroller.

A. Step-Down Transformer

The power supply unit of the suggested smart pesticide sprayer system relies heavily on the step-down transformer. Its major purpose is to lower the high-voltage AC mains supply to a lower AC voltage that is safe and appropriate for powering the electromechanical and electronic components. The transformer in this system usually transforms a 230 V AC input into a low-voltage output, like 12 V AC.

The transformer works on the basis of electromagnetic induction, in which a proportional voltage is induced in the secondary winding by a fluctuating magnetic flux created by an alternating current in the primary winding. By choosing a suitable turns ratio between the primary and secondary windings, the voltage is reduced. This technique preserves electrical isolation between the input and output while guaranteeing effective voltage transformation.

After passing via a rectifier circuit, the step-down transformer's low-voltage AC output is transformed into DC voltage. The corrected signal is subsequently smoothed using filtering elements like capacitors to lessen ripple and fluctuations. The ESP32 microcontroller, motor driver ICs, relay modules, and sensors are examples of sensitive components that require a steady and consistent DC output, which is then provided by a voltage regulator.

The step-down transformer not only converts voltage but also offers galvanic isolation between the low-voltage control circuitry and the high-voltage mains supply. By shielding the system and the user from electrical risks, voltage spikes, and short-circuit situations, this isolation improves operational safety. By lessening the effects of power-line disruptions, it also increases system dependability.

In agricultural settings where steady power delivery is crucial, the step-down transformer guarantees a dependable, secure, and stable power source for the smart sprayer system, allowing for continuous and effective operation.

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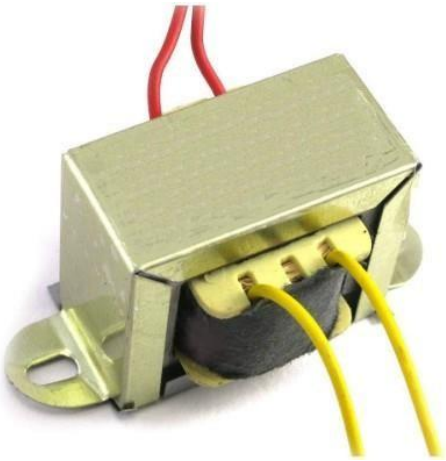


Fig. 5. Step-Down Transformer.

B. PSI Motor

The PSI motor is essential to ensuring accurate and efficient spraying of the pesticide solution onto crops. The ESP32 microcontroller's operation and control are depicted in Figure 8. The ESP32 regulates the motor's operation by turning it ON or OFF in response to user commands and system requirements. To securely control the high current required by the PSI motor, a relay module acts as an intermediary switching device. The relay, which is powered by the ESP32 and functions as an electrical switch, allows the motor to draw sufficient power without directly taxing the microcontroller. This arrangement protects the ESP32 from potential damage, phase disturbances, and voltage swings by establishing electrical isolation between the high-power motor circuit and the low-power control circuitry.

C. PSI Motor Operation

The PSI motor, shown in Figure 9, pumps the pesticide solution from the storage tank to the spraying mechanism. The motor and tank are connected by a network of pipes that efficiently transfer the solution.

When the user initiates the spraying process using the Arduino Bluetooth Controller application, the ESP32 microcontroller sends out a control signal to activate the relay module. When the relay is activated, the PSI motor starts to pump the pesticide solution through the pipes. The solution is then applied to the car's water sprinklers. By distributing the pesticide uniformly across the crop area, these sprinklers guarantee precise and effective administration.

The ESP32 microcontroller's Bluetooth connectivity enables the user to remotely turn the PSI motor on or off via a mobile application, giving real-time control over the spraying process. This remote-control capability reduces chemical waste and its detrimental effects on the environment by only using pesticides when necessary.

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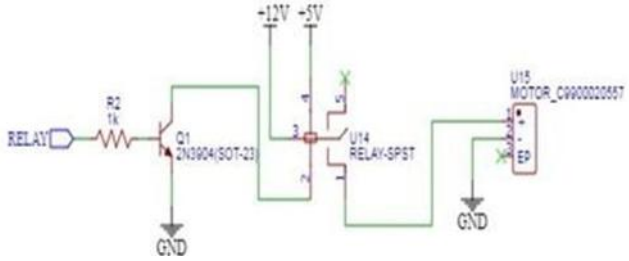


Fig. 6. Relay to PSI Motor Circuit Diagram.

Additionally, the system permits intermittent spraying according to crop requirements, allowing the operator to adjust the frequency and duration of spraying according to field conditions. The system offers precise, automated, and user-controlled pesticide spraying by connecting the PSI motor to the ESP32 microprocessor and controlling it via a Bluetooth- based application.



Fig. 7. PSI Motor.

D. L293D Motor Driver IC

The four DC motors that power the smart pesticide sprayer's wheels are controlled by the L293D IC, allowing it to move forward, backward, left, and right for autonomous navigation. Two L293D motor driver integrated circuits (ICs), each of which controls two DC motors, are used to effectively manage all motors.

DC motors can have their speed and direction controlled by the L293D, an H-bridge motor driver (Fig. 8). Through GPIO ports, the ESP32 microcontroller transmits PWM (Pulse Width Modulation) signals to the L293D ICs, allowing for exact control over motor speed and rotation. The technology accomplishes precise maneuvering in all directions by reversing the motor direction. Additionally, the ESP32 is shielded from electrical damage by the L293D ICs' safe handling of the greater voltage and current needed by the DC motors.

The ESP32 receives user commands via the Arduino Bluetooth Controller software, interprets them, and uses the L293D ICs to control the motors in real time, resulting in precise and fluid vehicle movement. In this project, the four DC motors that move the vehicle are smoothly and effectively controlled by the L293D motor driver ICs.

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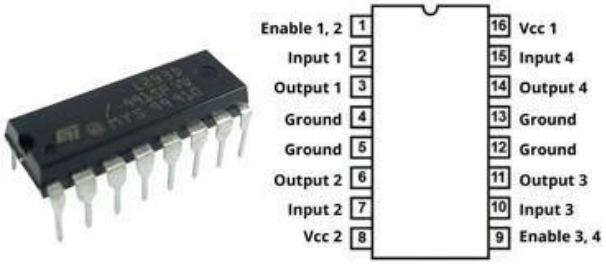


Fig. 8. Pin Configuration of L293D IC.

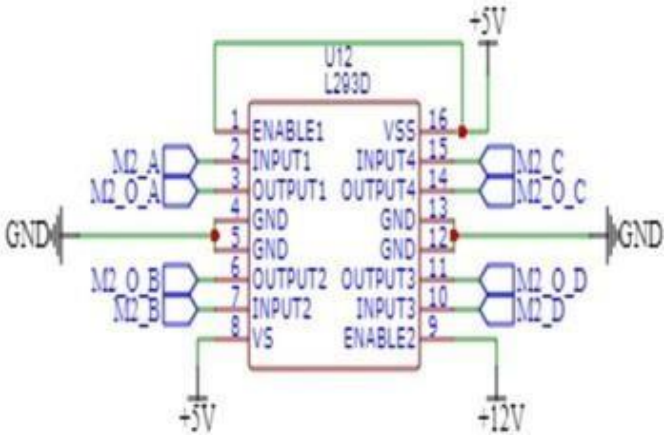


Fig. 9. Connection Diagram of L293D IC to DC Motor.

The car can move in all directions thanks to the use of two L293D ICs, which also offer manual control through the Bluetooth application. Furthermore, the L293D ICs contribute to system stability by giving the motors dependable power handling. In order to achieve exact navigation, which is necessary for efficient and regulated pesticide application, this integration is crucial.

E. LCM1027A2445F DC Motors

The vehicle in this project is driven by four LCM1027A2445F DC motors, as seen in Fig. 10. All four wheels can move forward, backward, left, and right in response to user orders thanks to these motors. The vehicle can function effectively and precisely navigate agricultural areas because of the high-performance DC motors LCM1027A2445F, which provide enough torque and speed.

The motors are controlled centrally by the ESP32 microprocessor. It produces control signals that are transmitted to two L293D motor driver integrated circuits (ICs), which serve as an interface between the DC motors and the ESP32. Pulse Width Modulation (PWM) allows each L293D IC to independently regulate motor speed and direction by controlling two motors.

The ESP32 receives user commands via the Arduino Bluetooth Controller application. After processing these inputs, the microcontroller instructs the L293D ICs to modify the motor's speed and polarity. The vehicle's smooth direction shifts and varied speed functioning are guaranteed by this coordinated control.

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Fig. 10. LCM1027A2445F DC Motor.

F. Water Pump

An integral component of the smart pesticide spraying system is the water pump, which moves the pesticide solution from the storage tank to the spraying mechanism. It ensures a constant and controlled flow of liquid to apply insecticides evenly across the agricultural area.

In the proposed system, the electrically driven water pump is indirectly controlled by the ESP32 microcontroller through a relay module. When the user instructs the ESP32 using the Bluetooth control application, the relay is activated, allowing the water pump to receive power. As a result, the pump begins to move the pesticide solution via the connected pipes.

Precise control over the spraying process is made possible by the use of a water pump, which minimizes waste and unnecessary pesticide use. Additionally, the system is appropriate for automated and remote agricultural applications since the pump's-controlled operation increases the sprayer's efficiency and dependability.

One essential component of automated spraying systems is the effective transfer of pesticide solution. A water pump is included to regulate the liquid flow from the storage tank to the spraying mechanism in order to satisfy this need. The system's total efficiency is increased, uniform pesticide distribution is guaranteed, and liquid waste is decreased thanks to the pump's-controlled operation.

Effective pesticide spraying requires a regulated liquid delivery mechanism. The water pump makes it easier for the pesticide solution to move smoothly from the storage tank to the spraying equipment. Its operation minimizes needless pesticide loss while ensuring uniform spraying.



Fig. 11. Water Pump.

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IV. RESULTS AND DISCUSSION

The functional functioning of each block depicted in the system block diagram was used to assess the performance of the suggested self-navigating smart sprayer. The integrated hardware modules demonstrated dependable control, monitoring, and pesticide spraying under simulated field circumstances, as proven by experimental testing.

The system received steady electrical power from the power supply unit, which was made up of a 12 V supply and a step-down transformer. The ESP32 microcontroller, motor driver, sensors, relay, and auxiliary components all operated without interruption thanks to the controlled supply. By separating the low-voltage control circuitry from high-voltage sources, the step-down transformer increased safety and improved system reliability.

As the core control unit, the ESP32 microcontroller efficiently coordinated the acquisition of sensor data, motor control, and spraying operations. Precise on/off switching of the spraying mechanism was made possible by the relay-controlled PSI motor and water pump's accurate response to control signals from the ESP32. By only applying pesticides, when necessary, this selective activation minimized chemical waste and its negative effects on the environment.

DC motors powered by the L293D motor driver IC were used for mobility tests. Through Motor 1 and Motor 2, the system produced smooth directional movement that permitted turning, forward, and backward motions. The ESP32 control signals were effectively amplified by the L293D driver, guaranteeing sufficient current delivery to the motors. The vehicle's capacity to operate steadily on a variety of surfaces suggests that it is appropriate for use in agricultural settings.

The IR sensor and soil moisture sensor interfaced with the ESP32 were used to validate environmental sensing. While the infrared sensor consistently identified obstructions, facilitating safe navigation, the soil moisture sensor offered helpful feedback on soil conditions. These sensor inputs helped regulate and context-aware spraying operations and improved decision-making abilities.

To signal system status, such as motor activation or sensor-triggered events, an auditory buzzer was integrated as an alert device. The buzzer improved user awareness and operational safety during testing by delivering timely and clear notifications.

Overall, the experimental findings showed that the prototype performed steadily and effectively. Reducing human work, maximizing pesticide consumption, and enabling semiautonomous operation were all made possible by the combination of inexpensive components with an ESP32-based control architecture. The outcomes demonstrate the viability of the suggested method for scalable implementation in precision agriculture, fostering efficiency, sustainability, and operator safety.

V. CONCLUSION

The self-navigating smart sprayer's successful creation for regulated pesticide application shows how automation and energy-efficient technology may be used effectively in contemporary agriculture. Through relay-based management of the PSI motor, the system incorporates an ESP32 microprocessor

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as the central control unit, allowing for precise regulation of pesticide spraying. In addition to avoiding chemical waste and lowering direct human exposure, this controlled process guarantees precise pesticide administration.

DC motors powered by an L293D motor driver IC enable autonomous mobility, allowing smooth forward, backward, left, and right movement in a variety of field situations. Realtime visual feedback is made possible by the integration of an ESP32-CAM module, which facilitates remote monitoring and better oversight of navigation and spraying operations. This feature guarantees improved control over the spraying process and enhances operational safety.

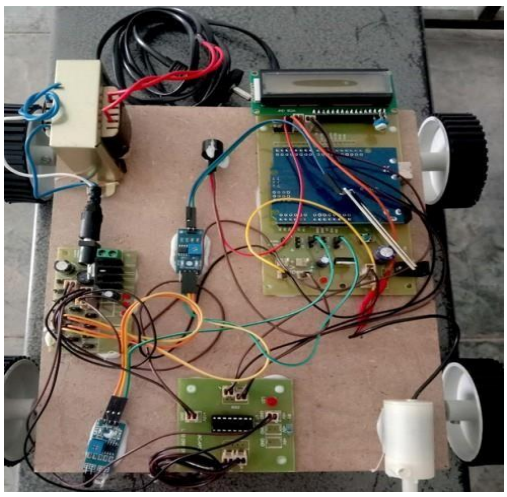


Fig. 12. Prototype Model of the Proposed Sprayer.

Self-sustaining operation without reliance on external power sources is made possible by the power architecture, which consists of a solar panel charging a 12 V battery and a voltage regulating device. The system is highly suited for agricultural settings and promotes environmentally sustainable practices because of its renewable energy-based design.

All things considered, the suggested smart sprayer greatly lowers manual labor, maximizes resource efficiency, and increases pesticide application safety. The prototype's successful implementation demonstrates its potential for wider adoption and practical deployment in precision agriculture, leading to safer, more effective, and sustainable agricultural methods.

Future developments in self-navigating pesticide sprayers are anticipated to concentrate on advanced sensing technologies, IoT-enabled connectivity, and artificial intelligence-based decision-making. Intelligent route planning and data-driven spraying techniques will be made possible by the integration of machine learning algorithms, GPS and GIS systems, and cloud-based data analytics. Efficiency and environmental safety will be further improved by new innovations like electrostatic spraying, drift control systems, real-time pest identification, and improved solar power systems. These developments will enable the creation of highly automated, scalable, and environmentally friendly solutions for future agricultural applications.

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