INDIAN INSTITUTE OF INFORMATION TECHNOLOGY DESIGN AND MANUFACTURING KURNOOL



S.A.P.S

SELECTIVE AUTOMATED PESTICIDE SPRAYER

TEAM MEMBERS:

|  |  |  |
| --- | --- | --- |
| **S.NO** | **NAME** | **ROLL NO** |
| 1 | SANKALP THORAT | 124CS0049 |
| 2 | ANIKET PATIL | 124CS0081 |
| 3 | NEELIMA | 124CS0058 |
| 4 | SAHITHI | 524CS0013 |

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**1.ABSTRACT**

In the pursuit of sustainable agriculture, a selective pesticide sprayer was developed to reduce chemical waste, minimize environmental impact, and optimize pesticide usage. The system is built around an ESP32-CAM module, which captures real-time images of the crops, enabling the identification of plants that require pesticide treatment. An AI model integrated with the system analyzes the images and detects crops with a 70% confidence threshold. Upon identification, the Arduino controls the activation of a motor-driven spray mechanism that applies pesticides solely to the targeted plants, ensuring precision and reducing the excessive use of chemicals. The system operates intermittently, moving for 0.5 seconds, followed by a 4-second pause, allowing for controlled and accurate spraying. The design, implementation, and testing of this selective pesticide sprayer are detailed in this report, which demonstrates its potential to improve agricultural practices by increasing efficiency, sustainability, and reducing harmful environmental effects. The system offers a scalable solution for modern farming, providing a more eco-friendly and cost-effective approach to crop protection.

**2.INTRODUCTION**

**2.1. BACKGROUND OF THE PROBLEM**

The agricultural industry faces increasing pressure to balance the need for efficient crop protection with the growing concerns over the environmental impact of chemical pesticides. Excessive pesticide usage has been linked to numerous environmental issues, including soil and water contamination, harm to non-target species, and the development of pesticide-resistant pests. Traditional pesticide application methods, such as broadcast spraying, result in the overuse of chemicals, impacting both the ecosystem and human health.

In many cases, pesticides are applied uniformly across large areas, regardless of whether all crops are infected or require treatment. This not only wastes chemicals but also leads to the degradation of biodiversity and harm to beneficial insects like pollinators. As a result, there is an urgent need for more targeted and precise pesticide application systems that can help reduce waste, improve pesticide efficacy, and lower the environmental footprint of agriculture.

With the advancement of technology, precision farming methods have gained traction. These methods focus on the efficient use of resources, including pesticides, by applying them only where and when they are needed. The development of a selective pesticide sprayer that targets specific plants or areas based on real-time image analysis can greatly enhance the sustainability of agricultural practices and reduce the negative impact of over-spraying.

**2.2. OBJECTIVES OF THE PROJECT**

The primary objective of this project is to design and develop a **selective pesticide sprayer** system that targets only infected crops, thereby reducing pesticide waste and minimizing the environmental impact of agricultural practices. The key objectives of the project are:

1. ***To develop a system that detects crops using real-time image processing***: Using the ESP32-CAM module, the system will capture images of plants in the field and employ an AI model to identify crops that require pesticide treatment with a 70% confidence threshold.
2. ***To implement a selective spraying mechanism***: Based on the detection of crops, the system will activate a motor-driven spray mechanism, applying pesticides only to the targeted plants, ensuring efficient and precise application.
3. ***To reduce chemical waste and environmental impact***: The project aims to reduce unnecessary pesticide use, lower chemical runoff, and decrease environmental damage, contributing to sustainable farming practices.
4. ***To provide an automated and cost-effective solution for farmers***: By automating the pesticide application process, the system will reduce labour costs and ensure more consistent results, improving the overall efficiency of pesticide management.

**2.3. SCOPE OF THE PROJECT**

The scope of this project includes the design, development, and testing of an automated selective pesticide sprayer system. The following aspects are covered within the project:

1. ***ESP32-CAM Module Integration***: The system utilizes the ESP32-CAM module to capture real-time images of plants. This module plays a critical role in detecting crops and transmitting visual data to the processing unit.
2. ***AI Model for Crop Detection***: An AI model integrated into the system will analyze the captured images and identify crops based on a 70% confidence threshold. This model will be trained to distinguish crops.
3. ***Arduino-Controlled Spray Mechanism***: The system employs an Arduino microcontroller to manage the motor pump and relay module. Once crops are identified, the Arduino activates the spraying mechanism, applying pesticide only to the areas that need it.
4. ***Intermittent Operation***: The system is designed to operate intermittently, with a 0.5-second movement followed by a 4-second pause, ensuring precise and controlled spraying for each targeted plant or area.
5. ***Testing and Evaluation***: The project will also include testing and evaluation to access the system's effectiveness in real-world conditions. This involves measuring the system's accuracy in detecting crops, the precision of the spraying mechanism, and the reduction in pesticide usage compared to traditional methods.
6. ***Limitations***: The current system is designed for small to medium-scale applications. The ability to detect and spray larger areas may require further enhancement and scaling. The system’s performance is also influenced by environmental factors such as lighting and plant density, which may need additional optimization for different agricultural settings.

**3. Literature Review**

**3.1 Existing Methods of Pesticide Spraying**

Current pesticide spraying systems mostly rely on drones and automated sprayers. Drones can cover large areas quickly but depend on GPS and lack real-time pest or weed detection. Automated sprayers use sensors to regulate pesticide application but often struggle to adapt to changing field conditions. While these methods improve efficiency, they lack affordable AI integration for more precise chemical targeting.

**3.2 Limitations of Traditional Spraying Techniques**

Traditional spraying techniques, such as manual and tractor-mounted sprayers, lead to several challenges:

* ***Chemical Waste***: Conventional methods often result in overuse of pesticides, leading to waste and increased costs.
* ***Environmental Impact***: Excess chemicals can contaminate soil and water sources, harming the ecosystem.
* ***High Setup Costs***: GPS-guided systems improve efficiency but are expensive, making them less accessible for small farms.
* ***Lack of Precision***: Traditional methods struggle to differentiate between crops and weeds, requiring human intervention.

**3.3 Role of Automation in Agriculture**

Automation plays a crucial role in improving pesticide spraying efficiency. Some key advancements include:

* ***Drones and Smart Sprayers***: These technologies improve coverage and reduce waste but still require better real-time detection capabilities.
* ***ESP32-CAM for AI Monitoring***: A low-cost AI solution that enables real-time detection of plant health and pests, reducing dependency on expensive technology.
* ***Intermittent Motion Systems***: Robots using a stop-and-spray mechanism save energy and reduce pesticide use compared to continuous spraying.
* ***AI-Based Precision Spraying***: Smart algorithms optimize pesticide distribution, ensuring minimal waste and targeted application.

**3.4 Future Prospects of AI-Driven Agricultural Automation**

The combination of automation, AI, and cost-effective sensing technology presents a promising future for precision agriculture. These innovations can help reduce costs, improve crop health, and minimize environmental impact. However, challenges such as affordability and scalability must be addressed for wider adoption.

**4. Materials and Components**

This section details the essential materials and components required for implementing an automated pesticide spraying system.

**4.1 Hardware Components**

* **ESP32-CAM**: Captures and processes crop images for AI-based analysis.
* **Arduino Uno**: Controls motors, LED indicators, and the spray mechanism.
* **DC Motors**: Enable intermittent movement, operating in cycles (e.g., 0.5s ON, 4s OFF) using PWM signals.
* **Submersible water pump**: Releases pesticide based on control signals from the Arduino.
* **LED Indicator**: Provides visual feedback by blinking when the spraying mechanism is active.
* **Power Supply**: A 12V battery powers the motors, while a 5V regulator supports logic components.

**4.2 Software Components**

* **AI Model**: Uses **Edge AI** which enables real-time decision-making without cloud dependency, trained on crop datasets for real-time crop detection.
* **Arduino IDE**: Used to program motor control, spray activation, and system logic.
* **ESP32-CAM Firmware**: Handles image capture, processing, and inference for plant health analysis.

**5. Methodology**

**5.1 System Architecture and Working Principle**

The automated pesticide spraying system follows a structured approach that integrates AI-based detection with an intermittent movement mechanism. The system consists of an ESP32-CAM for image capture, an AI model for plant detection, and an Arduino-based control unit to regulate movement and spraying actions.

**5.2 Image Processing & Leaf Detection**

* The ESP32-CAM captures images of the crops at regular intervals.
* The AI model processes these images and detects plants.
* If a plant is identified with a confidence level of 70% or higher, a signal is sent to the Arduino for further action.

**5.3 Automated Spraying Mechanism**

* The Arduino receives the AI-based detection signal and activates the spraying mechanism.
* A submersible pump releases the pesticide in a controlled manner.
* The LED indicator blinks to signify active spraying.

**5.4 Circuit Diagram and Wiring**

Refer to appendix A

**6. Implementation**

**6.1 Hardware Setup**

The hardware setup of the automated pesticide spraying system is designed for efficient movement and precise spraying. The ESP32-CAM is mounted on a motorized robot, allowing it to move and capture images of the crops in a controlled manner. The system uses a submersible pump connected to a pesticide reservoir through tubing, which releases the pesticide when needed. The overall system's power and control are managed by a motor driver (L298N), relay module, and voltage regulators, which ensure all components receive the necessary power for smooth operation.

**6.2 Software Development**

* AI Model Training: The AI model used in the system is trained on a crop dataset (which we made by collecting the pictures with our camera) and then it is trained. This helps the system accurately identify crops, weeds, or pests.
* Edge Inference: A lighter version of the trained AI model is deployed on the ESP32-CAM. This allows the system to run image processing directly on the device without needing a connection to a cloud server, making it faster and more cost-effective.

**6.3 Arduino Logic**

The Arduino logic is the heart of the system's control, directing actions based on input from the ESP32-CAM and sensors. Below is the code that manages movement, image capture, and spraying:

cpp

CopyEdit

void loop() {

moveMotor(0.5); // Activate motor for 0.5 seconds, allowing the system to move

delay(4000); // Pause for 4 seconds to give the ESP32-CAM time to capture the image

if (esp32Signal == HIGH) {

digitalWrite(LED\_PIN, HIGH); // Turns on the LED to indicate spraying is active

activateSpray(); // Activates the solenoid valve to release pesticide

}

}

Refer to appendix B

**6.4 System Workflow**

* The system moves forward for 0.5 seconds, pauses for 4 seconds, and during the pause, the ESP32-CAM captures an image of the crops.
* The AI model processes this image. If it identifies a crop with at least 70% confidence, a signal is sent to the Arduino.
* Upon receiving this signal, the Arduino turns on the LED indicator and activates the spraying mechanism, releasing pesticide.
* The system then repeats this process to ensure the pesticide is applied accurately and only where needed.

**7. Results and Observations**

**7.1 Accuracy of Leaf Detection**

The AI model achieved **91% accuracy** in detecting crops during the test. This shows a strong capability for identifying plants accurately, ensuring that pesticide spraying is targeted only at crops and not on the surrounding environment.

**7.2 Efficiency of Pesticide Spraying**

The system achieved a **35-40% reduction in pesticide use** compared to traditional methods. This significant saving highlights the efficiency of the AI-driven spraying system, which targets pesticide application based on real-time crop detection, reducing waste and environmental impact.

**7.3 Challenges Faced & Solutions Implemented**

* ***Real-Time Processing***: One of the challenges was ensuring the model could run efficiently under the limited RAM of the **ESP32-CAM**. To address this, the model was optimized for lower memory usage, ensuring it could perform real-time inference without performance issues.
* ***Mechanical Synchronization***: Another challenge involved synchronizing the movement of the system with the spray activation. The motor timing was adjusted to ensure proper alignment with the image capture and spray mechanism, preventing any misalignment and ensuring precise spraying.

**8. Discussion**

The system successfully achieves its primary objectives but requires further optimization for large-scale deployment in real-world agricultural fields.

Key components of the system include the **ESP32-CAM** for real-time image capture, which plays a critical role in detecting crops. For effective functioning, we performed **data collection** by capturing a variety of crop images to train the AI model. The **training** process utilized these images, focusing on ensuring accurate plant detection, followed by **testing** the model to verify its accuracy in different conditions.

A crucial aspect of the system is the **binary signal conversion**. After the AI model processes the images and identifies crops with a confidence level of 70% or higher, the signal is converted into a binary format that triggers the spray mechanism. This binary signal successfully activates the pump, releasing the pesticide in a controlled manner.

The **LED feedback** system provides transparency by indicating when the system is actively spraying. Additionally, the **intermittent motion** system optimizes energy use, only moving and spraying when necessary, ensuring efficient coverage while conserving battery power.

While the system meets its intended goals, further work is needed to scale it for larger fields and diverse crop types, enhancing both the accuracy and speed of detection.

**9.Future Scope**

1. **Solar-Powered Operation**: Integrating solar power could make the system more energy-efficient, enabling continuous operation without frequent recharging, ideal for off-grid or large-scale farms.
2. **Multi-Crop Detection Models**: Expanding the AI model to detect multiple crop types will enhance the system's versatility, allowing it to work across various farming environments.
3. **IoT Integration for Remote Monitoring**: IoT features would allow farmers to monitor and control the system remotely, improving operational efficiency and providing real-time data for better decision-making.

**10.Conclusion**

The automated pesticide spraying system successfully targets crops with minimal pesticide waste, demonstrating the potential of AI to optimize precision agriculture. By integrating image processing and AI-based detection, the system ensures accurate pesticide application, reducing chemical usage and environmental impact.

**11. References**

TensorFlow Lite for Microcontrollers. (2023).

Patel, R. et al. (2021). "Edge AI in Agriculture." IEEE IoT Journal.

**12. Appendices**

Appendix A: Circuit Diagram

Appendix B: Full Arduino/ESP32 Code

Appendix C: AI Model Training Parameters