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IoT Enabled Intelligent Pesticide Sprayer for Precision Agriculture (Krishi Rakshak Rover)

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Abstract – Our paper discusses the design and implementation of a low cost IoT enabled intelligent pesticide spraying system to boost efficiency in precision agriculture. The system combines the ESP32 Cam module with an Arduino nano, allowing for real time crop monitoring, wireless communication, and controlled pesticide application. A web based interface gives users access to the live video streaming, remote navigation control, camera angle adjustment, and pump operation through one dashboard.

Unlike traditional spraying methods that apply pesticides uniformly and continuously, this system lets users visually check field conditions and activate spraying only as needed. The web application also improves usability by offering support for multiple languages and an easy to use control layout, making it suitable for various users. Additionally, it includes an Ai based crop disease diagnosis feature that enables users to upload crop images and receive detailed analysis. This includes disease identification, preventive measures, and treatment suggestions.

Experimental results show that the system performs reliably with quick response times, stable communication, and effective real time control. By combining monitoring, control, and analysis into one platform, this system offers a practical and affordable solution for small and medium scale farmers. It promotes more efficient pesticide use while reducing environmental impact.

Keywords: IoT, Esp32 Cam, precision agriculture, smart farming, web-based control system, real time monitoring, Ai based disease detection.

I. INTRODUCTION

Agriculture plays a crucial role in feeding the growing global population, but keeping crops healthy is a significant challenge for farmers. Among different farming practices, pesticide spraying is commonly used to protect crops from pests and diseases. However, traditional spraying methods are mostly manual and often result in excessive and uneven application of chemicals. This raises operational costs, leads to environmental pollution, harms soil quality, and poses health risks for farmers.

With rapid technological advancements, incorporating the Internet of Things (IoT) into agriculture offers new ways to improve efficiency and precision. Smart farming techniques focus on using resources like water, fertilizers, and pesticides only when necessary, which reduces waste and boosts crop productivity. While modern solutions such as drones and automated farming robots are available, they tend to be expensive, complicated, and less accessible for small and medium sized farmers. Often these systems also lack real time monitoring and user interaction, which limits there effectiveness in changing the field conditions.

To tackle these issues, our work proposes an affordable IoT enabled intelligent pesticide spraying system that combines real time monitoring with remote operation. The system uses the ESP32 cam module to capture and stream the live video of the farm, letting users see crop conditions before deciding on actions. A web-based application serves as the main interface, allowing the users to control robot’s movement, adjust the camera, and activate the pesticide spraying mechanism from any device with internet access.

Unlike traditional systems that depend on constant spraying, this new approach supports selective and need based pesticide application. The user-friendly web interface includes features like live streaming, easy control options, and support for multiple languages, making it accessible and easier to use for farmers. Moreover, the system has an image-based crop analysis module, which allow users to upload plant images and receive insights about diseases along with suggested preventive and corrective actions.

By merging IoT connectivity, real-time visualization, and intelligent decision support into one platform, our proposed system presents a practical, cost-effective and scalable solution for precision farming. This approach not only cuts down unnecessary pesticide use but also promotes sustainable farming practices and enhances crop management.

II.LITERATURE SURVEY

Pesticide spraying in agriculture has changed significantly from traditional manual methods to modern automated systems. Understanding these changes helps shed light on the research gaps that the proposed system aims to fill.

Conventional manual pesticide spraying depends on handheld or tractor mounted sprayers. This approach remains popular due to its simplicity and low initial cost. However, studies have shown major drawbacks, including excessive chemical use, uneven distribution, and serious environmental contamination through soil and water pollution [1]. These issues have pushed researchers toward automated alternatives.

Early automated sprayers used fixed timers and preset settings to distribute pesticides at scheduled times. While these systems reduced the need for human involvement, they could not adapt to real-time field conditions. This often led to wasted chemicals and insufficient pest control [2]. The lack of decision-making ability in these systems pointed to the need for sensor driven, adaptive approaches.

The introduction of microcontroller-based platforms allowed for smarter control mechanisms. Systems using infrared (IR) and ultrasonic sensors were developed to detect crop and also field conditions, enabling conditional spraying instead of uniform application [3]. These embedded systems showed better efficiently but were limited to single-field use without coordination between systems.

Drone and robotic spraying platforms mark a significant advancement in automation. They provide aerial coverage, lower labor needs, and more precise targeting [4]. Despite these benefits, these systems come with high costs for purchase and maintenance, making them difficult for small farmers to access. Moreover, many drone solutions rely on pre-programmed flight paths and lack real-time adaptive decision-making.

The use of machine vision and deep learning techniques has added intelligent crop monitoring capabilities to precision agriculture. Systems that apply convolutional neural networks (CNNs) and image classification algorithms have proven effective at identifying pests, diseases, and weed infestations [5]. However, these methods require substantial computing power and high-resolution imaging, increasing overall costs and complexity.

IoT-based agricultural monitoring systems are gaining attention for their ability to collect and transmit sensor data wirelessly, allowing for remote analysis and control [6]. Platforms like ESP8266 and ESP32 have been widely used in affordable IoT prototypes for smart farming. They offer built-in Wi-Fi and enough processing power for real-time applications [7].

The ESP32-CAM module has emerged as a promising option for vision-based IoT systems. It combines a camera interface with Wi-Fi in a compact, low-cost package, making it ideal for precision agriculture applications [8]. Previous implementations show its effectiveness in live video streaming, remote monitoring, and basic image capture.

Solar-powered embedded systems have been studied to tackle power supply issues in remote agriculture. Research shows it is feasible to combine photovoltaic panels with rechargeable batteries to support continuous operation of IoT devices outdoors [10].

The review of our existing literature reveals that, although significant progress has been made in smart pesticide spraying, there is still a need for a unified, low-cost, and easy to deploy solution.

Our solution will combine real time visual monitoring, a web interface into a single, compact and affordable system for small and medium scale farms.

III. METHODOLOGY

A. System Overview

Our proposed system is an IoT-enabled pesticide spraying robot. We designed it for real-time monitoring and controlled pesticide application in agricultural fields. The system combines the ESP32-CAM module and Arduino Nano to manage image capture, wireless communication, and hardware control together.

The ESP32-CAM serves as the main unit for capturing live video and transmitting it over Wi-Fi. This lets users view field conditions remotely through a web-based interface on their smartphone or computer. The Arduino Nano handles control operations, including robot movement, pump activation, and servo positioning.

The robot uses DC motors connected to an L293D motor driver, which allows it to move forward, backward, left, or right. A DC water pump sprays pesticide and can be activated based on user input. A servo motor adjusts the camera's vertical angle, which enhances visibility and monitoring coverage.

A key part of our system is the web-based control interface. This is the main way users interact with the robot. Through the interface, users can watch live video, control movement, change the camera angle, and operate the spraying mechanism in real time. This setup ensures that pesticide spraying happens only when necessary, reducing waste and improving efficiency.

B. Block Diagram

The block diagram shows how the sensing, communication, control, and actuation units of the system work together. The ESP32-CAM serves as both the imaging and communication module. It captures real-time video and sends it to the web interface using Wi-Fi.

User commands from the web application reach the ESP32-CAM, which then forwards them to the Arduino Nano through serial communication. The Arduino Nano is the main control unit. It interprets these commands and manages the hardware components.

The L293D motor driver connects to the Arduino Nano to control the DC motors, allowing precise movement of the robot. The pesticide spraying mechanism, which includes a DC water pump, is also managed through the motor driver. A servo motor is connected to change the camera angle based on user input.

The whole system runs on a rechargeable battery, with a setup for solar-assisted charging to improve operational sustainability. The block diagram outlines a complete flow from real-time monitoring to user-controlled actuation, ensuring efficient and targeted pesticide spraying.

C. Flow Chart

Our proposed system works in a step-by-step process, shown in the flowchart. First, the system powers on and initializes both the ESP32-CAM and Arduino Nano. The ESP32-CAM connects to the local Wi-Fi network and starts streaming live video to the web interface.

After the connection is established, the user accesses the web application to monitor field conditions in real time. Based on what they see, the user sends control commands through the interface. These commands can include movement direction, camera adjustment, or spray activation.

The ESP32 Cam receives these commands and sends them to the Arduino Nano using serial communication. Arduino Nano processes the commands and controls the motor driver to move the robot or activate the pesticide pump. At the same time, the servo motor adjusts the camera angle as needed.

This process repeats continuously, allowing for ongoing monitoring and control until the system is powered off. The workflow provides smooth interaction between user input and hardware response, enabling effective and controlled pesticide application.

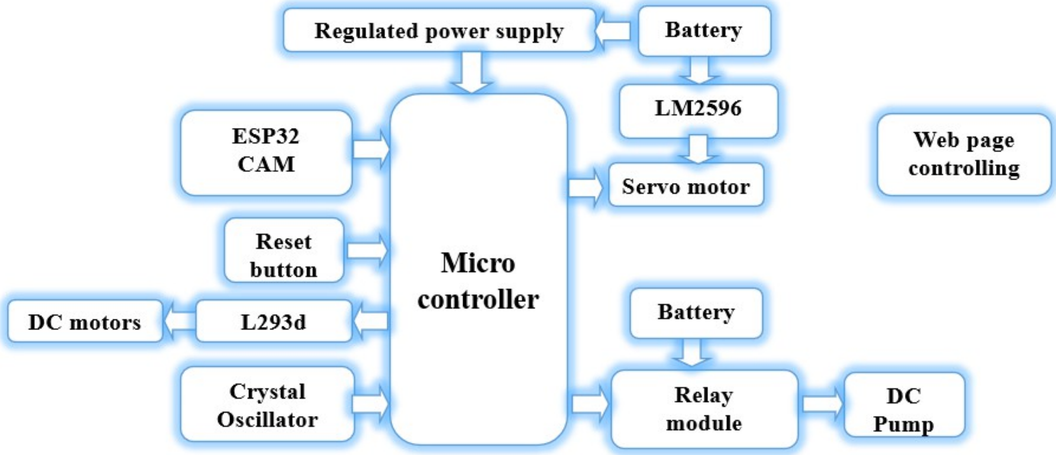


Fig.1. Block diagram illustrating overall the system architecture

D. Circuit Diagram

The circuit diagram of the proposed system shows the detailed pin-level connections between the ESP32-CAM, Arduino Nano, motor driver, and actuators. The ESP32-CAM communicates with the Arduino Nano using serial communication. The U0TXD (GPIO1) of the ESP32-CAM connects to the RX pin (D0) of the Arduino Nano, while the U0RXD (GPIO3) connects to the TX pin (D1). Both modules share a common ground. The Arduino Nano controls the L293D Motor Driver with digital output pins. The IN1, IN2, IN3, and IN4 pins of the L293D connect to Arduino pins D2, D3, D4, and D5, respectively, for controlling the direction of the DC motors. The enable pins ENA and ENB of the motor driver connect to PWM pins D9 and D10 for speed control. The four DC motors connect to the output pins (OUT1–OUT4) of the L293D, allowing the robot to move in all directions.

Our pesticide spraying system includes a DC water pump linked to one of the motor driver output channels, like OUT3 and OUT4. This setup lets the pump switch ON or OFF through Arduino control. A servo motor for adjusting the camera angle connects to PWM pin D6 of the Arduino Nano. The system uses a 12V battery linked to the VCC2 pin (pin 8) of the L293D to power the motors. A regulated 5V supply feeds the Arduino Nano through the VIN or 5V pin and the ESP32-CAM. All ground terminals connect together to provide a common reference. An optional solar panel can be added through a charging module to recharge the battery, ensuring ongoing operation in the field.

In summary, the circuit ensures reliable communication, precise motor control, and efficient power distribution for real-time monitoring and pesticide spraying.

Fig.2. Flowchart of the Proposed System

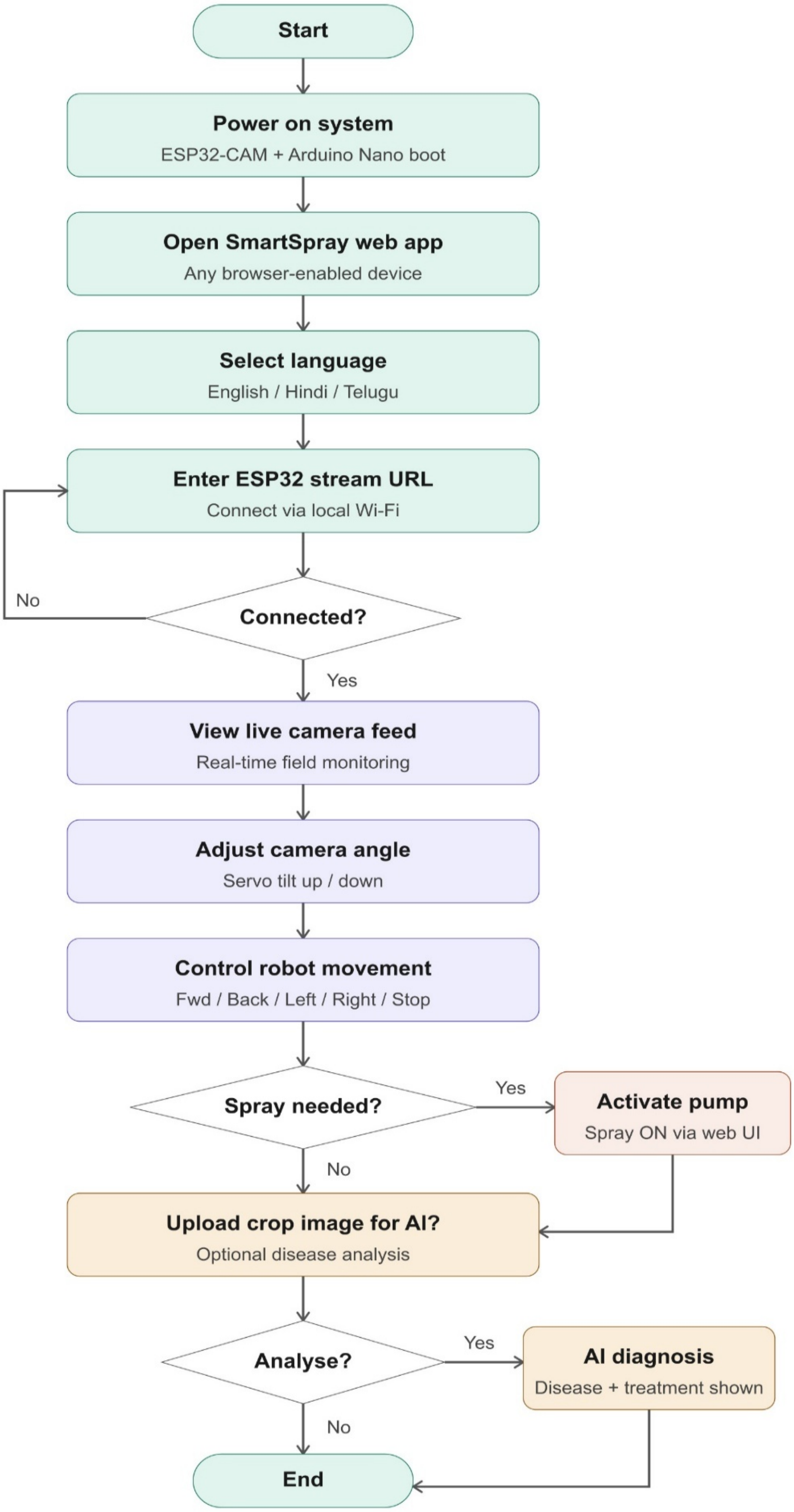
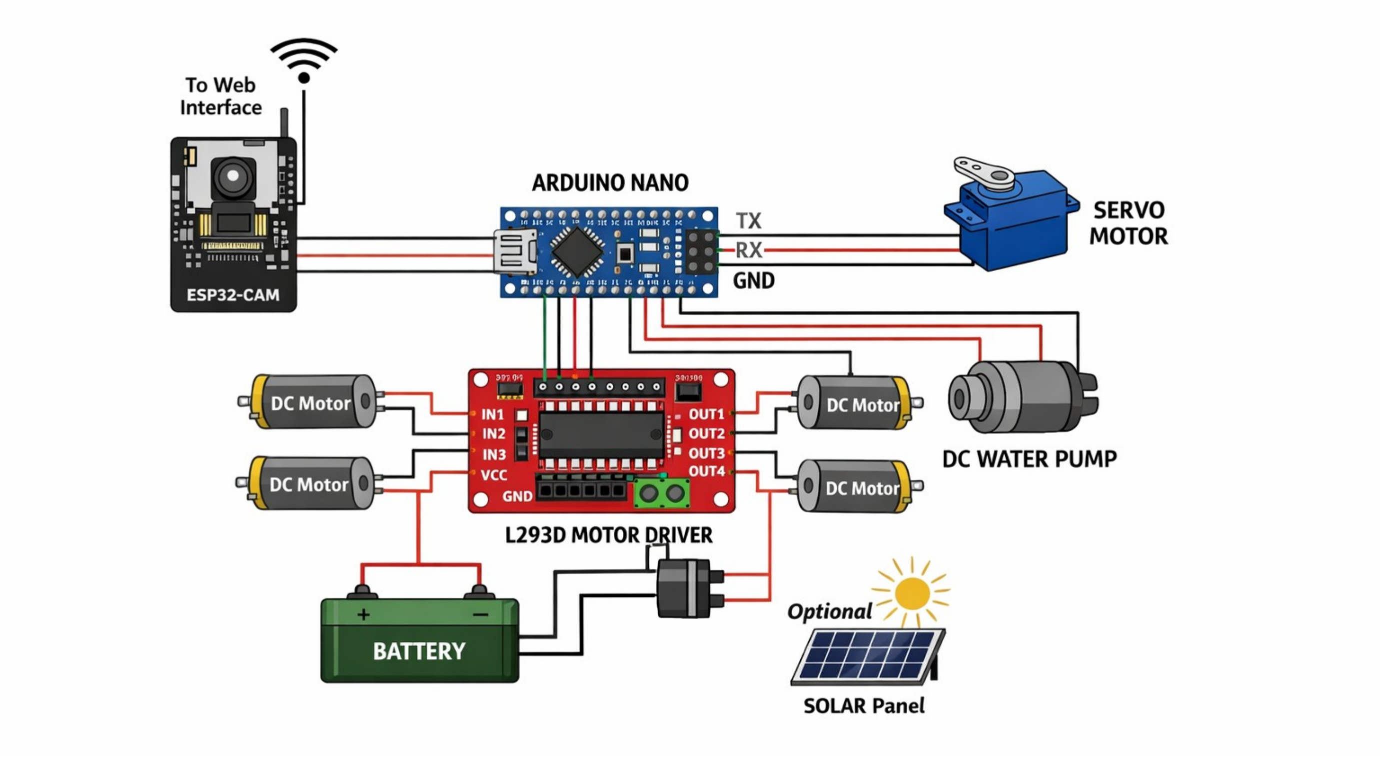


Fig.3. Circuit Diagram of the Proposed System



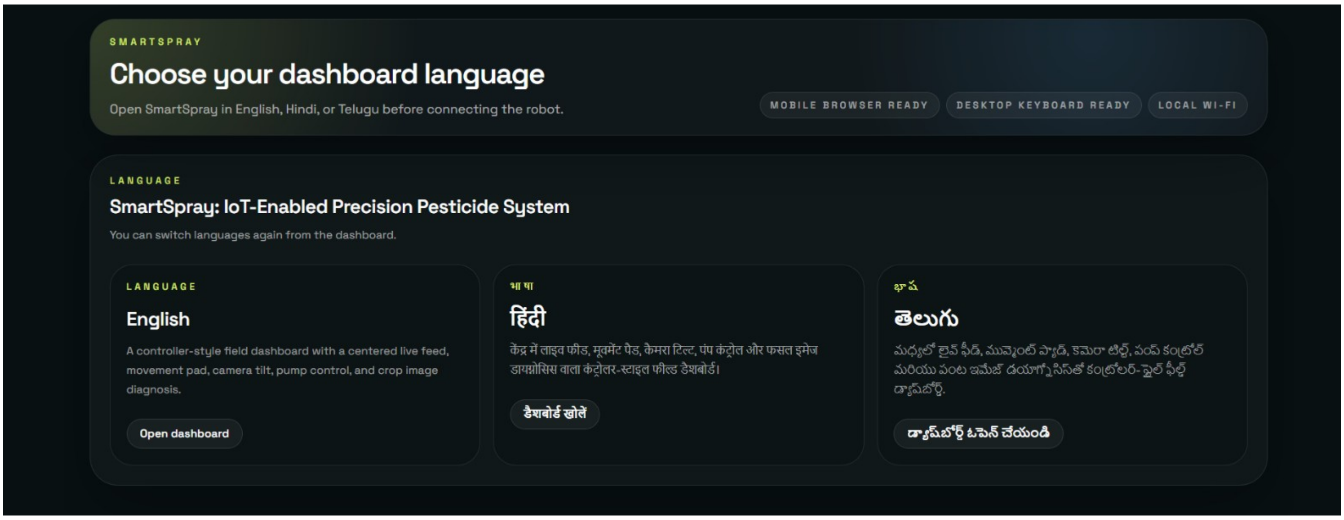
E. Web Interface

The system they are talking about has a website that people use to interact with it and control it. This website is easy to use. It helps people watch and control the robot that sprays pesticides in real time.

The website shows a video from the ESP32-CAM camera so people can see how the crops are doing from far away. It has a control panel that lets people move the robot around using buttons on the screen or their keyboard. People can also use the website to change the angle of the camera, which helps them see more of the field.

The website also lets people turn the pesticide spray on and off. It shows whether the

Fig.4. Multi-language web interface homepage showing language selection and platform readiness for remote field operation.



SMARTSPRAY

Choose your dashboard language

Open SmartSpray in English, Hindi, or Telugu before connecting the robot.

LANGUAGE

SmartSpray: IoT-Enabled Precision Pesticide System

You can switch languages again from the dashboard.

LANGUAGE

English

A controller-style field dashboard with a centered live feed, movement pad, camera tilt, pump control, and crop image diagnosis.

भाषा

हिंदी

केंद्र में लाइव फीड, मूवमेंट पैड, कैमरा टिल्ट, पंप कंट्रोल और फसल इमेज डायग्नोसिस वाला कंट्रोलर-स्टाइल फील्ड डैशबोर्ड।

భాష

తెలుగు

మధ్యలో లైవ్ ఫీడ్, మువ్మెంట్ ప్యాడ్, కెమెరా టిల్ట్, పంప్ కంట్రోల్ మరియు పంట ఇమేజ్ డయాగ్నోసిస్‌తో కంట్రోలర్-స్టైల్ ఫీల్డ్ డ్యాష్‌బోర్డ్.

commands are working and if the system is connected, which makes it more reliable and people feel more confident using it.

The website is available in languages so people who speak different languages can use it. It also has a feature that lets people upload pictures of their crops and get information about what might be wrong, with them and how to fix it.

So the website is really important because it lets people watch, control and analyze the crops all in one place. This makes the whole system work better and helps people use pesticides in a precise and efficient way. The pesticide spraying robot and the website work together to make this happen. The website is the way that people interact with the pesticide spraying robot.

Fig. 5. Web-Based Live Monitoring and Robot Control Dashboard

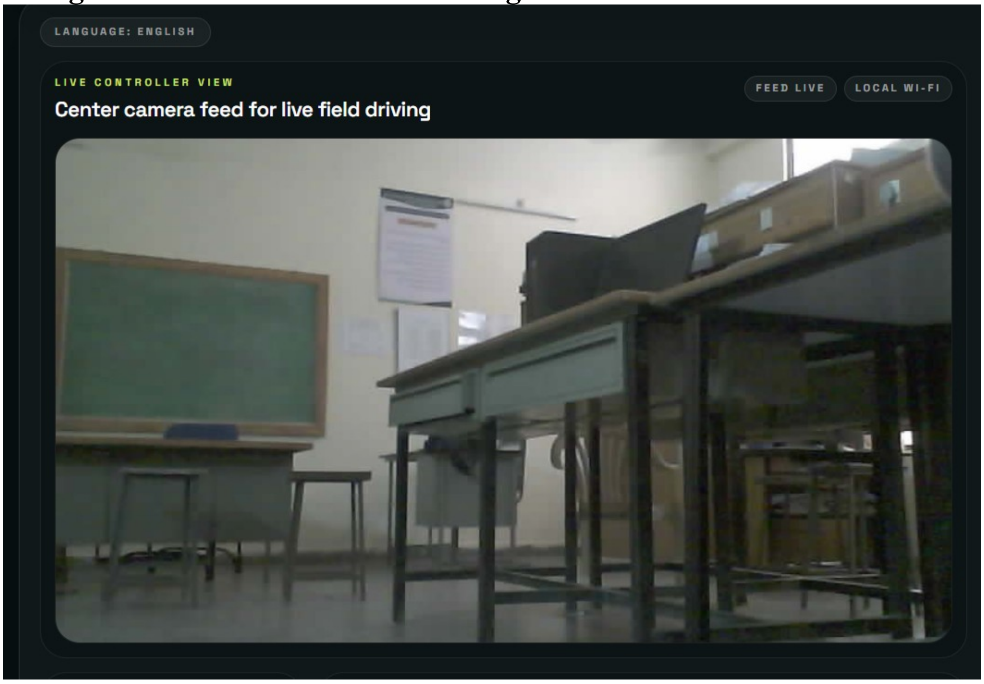
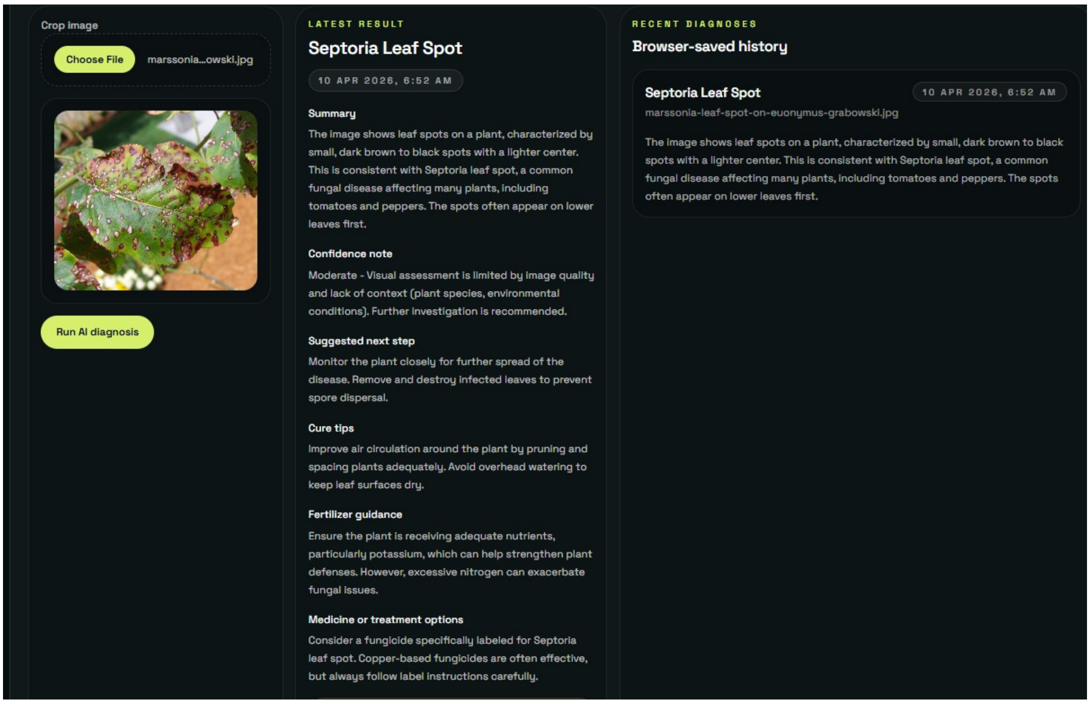


Fig. 6. AI-Based crop disease diagnosis result showing Septoria leaf spot detection, symptom analysis, confidence assessment, and recommended treatment measures



LATEST RESULT

Septoria Leaf Spot

10 APR 2026, 6:52 AM

Summary

The image shows leaf spots on a plant, characterized by small, dark brown to black spots with a lighter center. This is consistent with Septoria leaf spot, a common fungal disease affecting many plants, including tomatoes and peppers. The spots often appear on lower leaves first.

Confidence note

Moderate - Visual assessment is limited by image quality and lack of context (plant species, environmental conditions). Further investigation is recommended.

Suggested next step

Monitor the plant closely for further spread of the disease. Remove and destroy infected leaves to prevent spore dispersal.

Cure tips

Improve air circulation around the plant by pruning and spacing plants adequately. Avoid overhead watering to keep leaf surfaces dry.

Fertilizer guidance

Ensure the plant is receiving adequate nutrients, particularly potassium, which can help strengthen plant defenses. However, excessive nitrogen can exacerbate fungal issues.

Medicine or treatment options

Consider a fungicide specifically labeled for Septoria leaf spot. Copper-based fungicides are often effective, but always follow label instructions carefully.

RECENT DIAGNOSES

Browser-saved history

Septoria Leaf Spot 10 APR 2026, 6:52 AM
marssonia-leaf-spot-on-euonymus-grabowski.jpg

The image shows leaf spots on a plant, characterized by small, dark brown to black spots with a lighter center. This is consistent with Septoria leaf spot, a common fungal disease affecting many plants, including tomatoes and peppers. The spots often appear on lower leaves first.

IV. RESULTS AND ANALYSIS

Our IoT-enabled intelligent pesticide spraying system was tested in an area that was set up to look like a small farm. This system had a lot of parts including an ESP32-CAM module that let us see video, an Arduino Nano that controlled the hardware and motors that made the robot move. The robot also had a motor that moved the camera and a pump that sprayed pesticides. All of this was powered by a 12V battery. Connected to a local Wi-Fi network so we could talk to it in real time.

When we tested the system the ESP32-CAM module worked well and sent us live video all the time. We could use this video to look at the crops from away and tell the robot what to do without going into the field. It took about 1.5 to 2 seconds for the robot to do what we told it to do. This was because of the time it took to send the message process it and make it happen. The system was very reliable. Only stopped working a little bit when the signal was weak.

The robot moved around smoothly in all directions. We could use a pad on the website to tell it where to go and it worked really well. We could also use the keyboard. Touchscreen to control it which made it easier to use. The motor that controlled the wheels worked well and the robot did a great job on flat ground.

The live video from the camera was really helpful for looking at the crops. We could move the camera up and down to see the crops from angles, which helped us make better decisions about spraying pesticides. The system also told us when it was connected and what was happening, which made it more reliable and easier to use.

The pesticide sprayer worked well too. We could turn it on and off from the website. It only sprayed when we needed it to. This was better than spraying all the time because it used less pesticide and did not waste as much. The system was really good at spraying pesticides in the places and it helped us farm in a way that was good for the environment.

One of the things about the system was that it could also help us figure out if the crops were sick. We could upload pictures of the leaves to the website. It would tell us what was wrong with them. For example it could tell us if the leaves had a disease called Septoria leaf spot and it would give us advice on how to fix it. We could also look at the history of the crops. See how they were doing over time.

Overall the system worked well. It let us watch the crops in time control the robot spray pesticides only when we needed to and figure out if the crops were sick. It was a lot better than the way of doing things because it used less pesticide was easier to use and helped us make better decisions. It was also pretty cheap and easy to use, which makes it a great tool, for medium-sized farms.

Fig.4. Hardware Prototype

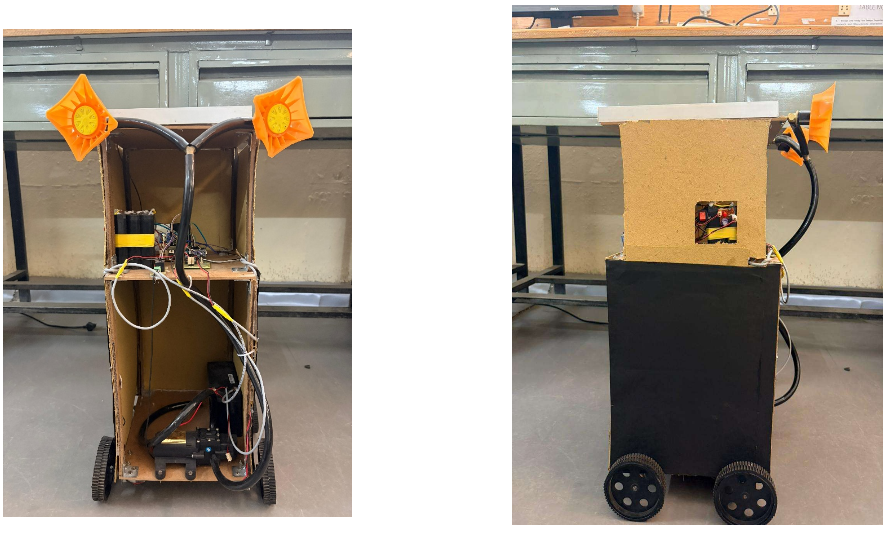


Table of Performance Comparison with existing systems

Parameter	**Manual Spraying**	**Drone Based**	**Ai Smart Systems**	**Proposed IoT Based Intelligent Sprayer**
Cost	Low	Very High	High	Affordable
Pesticide Utilization efficiency	~30%	Up to 65%	65 to 70%	80 to 90%
Water consumption	Very high	Reduced up to 65%	optimized	Selective spraying so very less
Response time	slow	fast	automated	1.5 to 2 sec
Coverage area	Very low	Very high	Medium to high	medium
Precision	low	high	high	Based on the operator
Real time monitoring	no	limited	Yes	Live streaming
Environmental Impact	High	Medium	Low	Low
Complexity	Low	High	Very high	Moderate
Suitability	Small farms	Large farms	Advanced farms	Small & medium farms

V.CONCLUSION

Our work is about an IoT-enabled intelligent pesticide spraying system. It helps with precision agriculture by watching the fields and only spraying when it is necessary. The system has hardware and software parts that work together. It lets farmers see how their crops are doing from away and take action when they need to. The system can send messages without wires show video and spray pesticides only where it is needed. This makes it better than the way of spraying pesticides by hand.

One good thing about this system is that it has a website that farmers can use to talk to the robotic system. They do not need to use different tools to watch their crops and control the system. The website lets them do everything they need to do in one place. They can move the robot around adjust the camera control the spray and look at pictures of their crops. This makes the system easy to use and good for farmers. The website can also be used in languages, which is good for farmers from different places.

Our system is also good because it can help farmers figure out if their crops are healthy. They can upload pictures of their crops. Get information about what might be wrong with them. This helps farmers make decisions and makes the system more useful. It is not a robot that sprays pesticides it is a whole system that helps farmers take care of their crops.

Our system is good for medium-sized farms. It is affordable. Can be used by many farmers. It helps farmers use their resources well reduces the amount of chemicals they use and is good for the environment. This system shows that new technologies can be used to make farming. It uses low-cost parts and website technologies to make a system that's useful, for farmers.

VI. FUTURE SCOPE

Our proposed system lays a solid groundwork for smart pesticide spraying, but several improvements can boost its performance, automation, and scalability. One important future enhancement is the addition of real-time pest and disease detection using lightweight machine learning or Tiny ML models. This would allow the system to automatically identify affected crops and trigger spraying actions without constant user input, leading to a more autonomous solution.

Adding more environmental sensors, such as those for soil moisture, temperature, and humidity, can improve the system's decision-making ability. By merging sensor data with visual monitoring, the system can offer more accurate insights into crop health and field conditions, allowing for better resource management.

Navigation can improve by integrating GPS and intelligent path-planning algorithms. This would enable the robot to follow set routes or cover larger areas on its own, lessening the need for manual control and making the system more suitable for broader agricultural uses.

On the software side, expanding the current web-based platform to support cloud connectivity can greatly enhance accessibility and functionality. Cloud integration would let users monitor and control the system from remote locations outside the local network, while also enabling data storage, analysis, and long-term tracking of crop conditions.

The pesticide spraying mechanism can improve by adding adjustable nozzles and flow control techniques. This would allow precise regulation of spray intensity and direction, increasing efficiency and reducing chemical waste. With these improvements, our system can develop into a smarter, more autonomous, and scalable option, capable of meeting the rising needs of modern precision agriculture while staying affordable and easy to use.