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Smart Laser Repellent Technology for Sustainable Farming

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Abstract: Agriculture is one of the most important sectors supporting the economy and food production worldwide. However, crop damage caused by birds, wild animals, and intruders significantly reduces agricultural productivity and farmer income. Traditional crop protection methods such as fencing, scarecrows, and manual monitoring are inefficient, labor-intensive, and environmentally harmful. This paper proposes an IoT-based Smart Laser Repellent System for Sustainable Farming that automatically detects and repels birds and animals using laser technology and intelligent monitoring systems. The proposed system uses PIR sensors, ESP32 microcontroller, laser modules, and servo motors to detect movement and activate a rotating laser beam for repelling intrusions without causing physical harm. IoT connectivity enables real-time monitoring and mobile notifications to farmers. The system provides an eco-friendly, cost-effective, energy-efficient, and sustainable solution for modern smart agriculture applications. Experimental analysis demonstrates improved crop protection efficiency, reduced labor dependency, and minimized environmental impact compared to traditional farming protection methods.

Keywords: Smart Farming, Sustainable Agriculture, IoT, Laser Repellent System, ESP32, Crop Protection, Precision Agriculture, Wildlife Detection.

I. INTRODUCTION

Agriculture plays a major role in economic development and food security across the world. Farmers often experience severe crop losses due to birds, wild animals, and intruders entering agricultural fields. These intrusions damage crops, reduce productivity, and increase economic losses. Traditional protection methods such as fencing, scarecrows, chemical repellents, and manual guarding are costly, inefficient, and require continuous human effort.

Birds and wild animals are highly active during early morning and nighttime, making continuous monitoring difficult for farmers. Conventional methods also fail to provide reliable protection over large agricultural areas.

Furthermore, chemical repellents can negatively affect the environment and crop quality.
With the advancement of Internet of Things (IoT) technology and smart farming practices, intelligent crop protection systems can be developed to automate monitoring and repellent mechanisms. Laser-based repellent systems provide a non-lethal and environmentally friendly solution for protecting crops from birds and animals.

This paper proposes an IoT-based Smart Laser Repellent System designed to detect movement using PIR sensors and activate rotating laser beams through servo motors. The system uses an ESP32 microcontroller for intelligent processing and IoT communication for real-time farmer notifications. The proposed solution improves crop safety, reduces manual intervention, and supports sustainable agricultural practices.

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The main objectives of the proposed system are:

- To develop an automated crop protection system using laser repellent technology.
- To detect birds and animal movement using PIR sensors.
- To reduce crop damage using non-lethal laser-based repellent mechanisms.
- To integrate IoT technology for remote monitoring and farmer notifications.
- To reduce labor dependency and operational cost.
- To support sustainable and eco-friendly farming practices.

II. RELATED WORK

Several researchers have developed smart farming and automated crop protection systems using IoT and sensor technologies.

A study on laser bird repellent systems introduced automated rotating laser modules for preventing bird attacks in agricultural fields. The system demonstrated improved crop protection efficiency compared to traditional scarecrow methods.

Researchers have also proposed IoT-based smart agriculture systems that monitor environmental conditions and automate irrigation, pest control, and field monitoring operations using sensors and wireless communication technologies.

Another research work focused on wildlife intrusion detection systems using PIR sensors and image processing techniques. These systems automatically detect animal movement and generate alerts for farmers.

Embedded systems using microcontrollers such as Arduino and ESP32 have also been widely used for agricultural automation due to their low power consumption, low cost, and wireless connectivity capabilities.

Although previous systems provide effective monitoring and automation, many solutions are expensive, complex, or unsuitable for rural farmers. Therefore, this work proposes a simple, low-cost, eco-friendly, and scalable Smart Laser Repellent System for sustainable farming applications.

III. PROBLEM STATEMENT

Farmers face serious challenges in protecting crops from birds and wild animals. Traditional methods such as fencing, scarecrows, and manual monitoring are inefficient and require continuous human effort. Chemical repellents may harm the environment and reduce crop quality.

Major problems faced by farmers include:

- Frequent crop damage by birds and animals.
- High labor dependency for field monitoring.
- Ineffective traditional protection techniques.
- Increased financial loss due to reduced crop yield.
- Lack of automated and real-time monitoring systems.
- Environmental pollution caused by chemical repellents.

These challenges reduce agricultural productivity and affect sustainable farming practices. Therefore, an intelligent automated crop protection system is required to improve efficiency and minimize crop losses.

IV. METHODOLOGY

The proposed Smart Laser Repellent System integrates IoT, automation, and intelligent monitoring technologies to protect agricultural crops from birds and wild animals. The methodology is divided into four major stages: power management, intrusion detection, processing and control, and remote monitoring.

A. Power Supply and Energy Management

The system is powered using a solar panel connected to a rechargeable lithium-ion battery. The battery output is regulated using a DC-DC buck converter to provide stable 5V/12V power for all hardware components. This ensures continuous operation even during power outages and supports sustainable farming practices through renewable energy usage.

Components Used:

- Solar Panel
- Li-ion Battery
- Buck Converter

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- Regulated Power Supply Function:
- Provides uninterrupted power to the complete system.
- Supports eco-friendly and low-power operation.

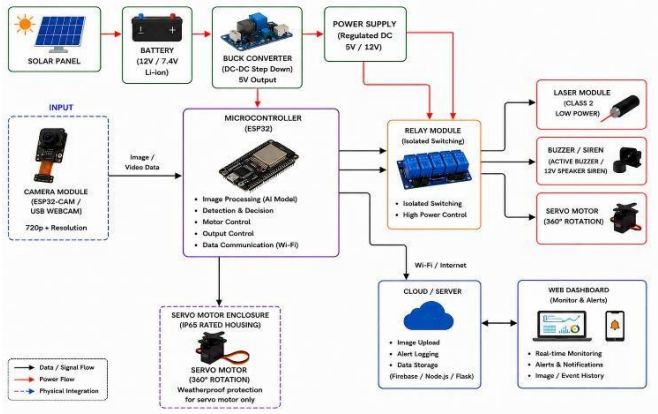

Fig. 1. Block Diagram of Smart Laser Repellent System

B. Intrusion Detection Module

The intrusion detection system uses an ESP32-CAM or USB webcam to continuously monitor the agricultural field. The camera captures image and video data, which is sent to the ESP32 microcontroller for processing.

The AI-based detection mechanism identifies movement caused by birds, animals, or intruders. Once an intrusion is detected, the controller activates the repellent system automatically.

Components Used:

- ESP32-CAM / USB Webcam
- ESP32 Microcontroller Functions:
- Real-time image acquisition
- Motion and intrusion detection
- AI-based decision making

C. Repellent and Control Module

After detecting movement, the ESP32 controller activates the relay module, which controls the laser module, buzzer, and servo motor.

The servo motor rotates the laser beam through 360° coverage to repel birds and animals from the farming area. Simultaneously, the buzzer produces warning sounds for additional protection.

Components Used:

- Relay Module
- Laser Module
- Servo Motor
- Buzzer/Siren Functions:
- Rotating laser activation
- Audio warning generation
- Wide-area protection coverage

D. IoT Monitoring and Cloud Integration

The system uses Wi-Fi communication for transmitting data to a cloud server. The captured images, intrusion alerts, and system logs are stored in the cloud database.

A web dashboard enables farmers to monitor real-time field conditions, view intrusion alerts, and access image history remotely using smartphones or computers.

Components Used:

- Wi-Fi Communication
- Cloud Server
- Web Dashboard Functions:
- Real-time remote monitoring
- Alert notification system
- Data logging and storage

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VI. RESULTS AND DISCUSSION

The proposed Smart Laser Repellent System was successfully designed and tested for automated crop protection applications. Experimental observations demonstrated effective detection and repellent operations under different environmental conditions.

The camera module successfully captured real-time images and detected the presence of birds and small animals entering the protected farming area. The ESP32 controller processed the intrusion data and activated the laser module automatically.

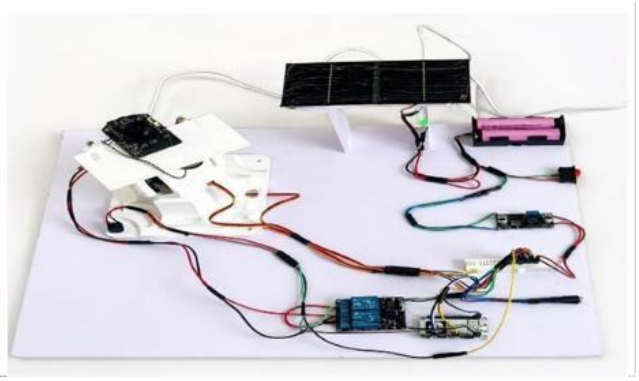

Figure 2: Developed Model for Sustainable Farming Protection

The rotating servo motor improved laser coverage and effectively repelled birds and animals without causing physical harm. The buzzer system provided additional warning alerts, improving overall protection efficiency.

The IoT-based monitoring system successfully transmitted real-time notifications and intrusion logs to the cloud server. Farmers were able to monitor field activity remotely using the web dashboard interface.

Observed Results:

- Reduced bird and animal intrusion frequency
- Improved crop protection efficiency
- Reduced human monitoring effort
- Stable operation using solar power
- Low power consumption
- Successful cloud-based alert monitoring

The proposed system provided better performance compared to conventional scarecrow and fencing methods. The use of renewable energy and non-lethal laser technology also supported sustainable and eco-friendly agricultural practices.

VII. CONCLUSION

This paper presented an IoT-Based Smart Laser Repellent System for Sustainable Farming. The proposed system effectively detects and repels birds and wild animals using image processing, laser technology, and automated control mechanisms.

The integration of ESP32 microcontroller, camera module, servo motor, and cloud monitoring provides a smart and intelligent crop protection solution. The system minimizes crop damage, reduces labor dependency, and supports real-time remote monitoring through IoT communication.

The use of solar energy makes the system environmentally friendly and suitable for rural agricultural applications. Therefore, the proposed smart farming solution offers a low- cost, energy-efficient, scalable, and sustainable approach for modern crop protection systems.

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